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Title of Dissertation: The Effects of Physical Conditioning on Mental Performance

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ABSTRACT

This study was designed to determine the effects of an aerobic physical conditioning program on the ability to perform selected mental performance tasks by normal healthy adults. Subjects were volunteers working as junior house-staff at the Walter Reed Army Medical Center. All subjects underwent a maximal graded exercise test to determine maximal oxygen consumption (VO2max), an objective measure of aerobic fitness. The subjects then completed ten sessions of a mental Performance Assessment Battery ("PAB") which included both single and double-digit addition, a logical reasoning task, and a spatial pattern recognition task. The ten testing sessions were administered at randomized times of the day to allow separation of learning effects from time of day effects.

The subjects were randomly assigned into one of two groups: a control group, and an exercise group which was enrolled in an individualized exercise program. Compliance was monitored via exercise logs and bi-weekly meetings. Four months were allowed for the exercise group to become conditioned. At the end of this time the maximal exercise

test and the PAB were repeated.

Of the 35 subjects who started the study, seven control and seven exercise-group subjects participated until completion. Four of the subjects in the exercise group showed average increases in VO2max of approximately 20 percent. The remaining subjects showed no changes in VO2max. There was no effect of conditioning on any aspect of mental performance or on the circadian rhythm of mental performance. This was true if one considered the four conditioned subjects versus the controls or all seven subjects in the exercise group versus the controls. An analysis of the beta-error was performed at a power level (1 - beta error) of 0.75. By this analysis there is a less than one in 20 chance that the effect of conditioning was greater than approximately 10 percent for the two addition and the logical tasks and 80 percent for the spatial task.

This prospective, randomized study of normal subjects demonstrated a lack of effect of quantified increases in aerobic capacity on reproducible measures of mental performance.

THE EFFECTS OF PHYSICAL CONDITIONING ON MENTAL PERFORMANCE

by

Timothy Jerner Gawne

Dissertation submitted to the faculty of the Department of Physiology Graduate Program of the Uniformed Services University of the Health Sciences in partial fulfillment of the requirements of Doctor of Philosophy 1984

DEDICATION

Dedicated to the memory of Bill the Cat (tm). Had He lived and gone on to graduate school, I like to think that this is the sort of dissertation that He would have written. Ack!

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TABLE OF CONTENTS

List of Tables xi

List of Figures xii

List of Appendices xiv

Introduction 1

Mental Performance 2

Aerobic vs Anaerobic Exercise 4

Physiology of Aerobic Exercise 5

Physiology of Aerobic Conditioning 7

Effects of Conditioning on the Cardiovascular System 8

Effects of Exercise on Sleep 9

Effects of Exercise on Personality 11

Effects of Exercise on Mood/Affect 12

Effects of Exercise on Mental Performance 13

Effects of Exercise and Conditioning on Circadian Rhythms 15

Effects of Physiological Changes on:

Psychological States 17

Thyroid Hormones 18

Central Amines 19

Endorphins 20

Testosterone 21

Effects of Circadian Rhythms on Mental Performance 22

Conclusions 24
Specific Aims 24
Materials and Methods 26
Overview 26
Subjects 27
Body Fat Determination 28
Exercise Testing Protocol 29
Mental Performance Tests 32
ADD2 35
PAULI 35
LOGI 36
MAT1 and MAT2 36
PROBEMEM 37
MAST2 and MAST6 37
PAB Scoring 37
Conditioning Program 38
Statistics 40
Results 41
Pilot Study, Anthropometric Data 41
Pilot Study, Mental Performance Data 44
Longitudinal Study, Anthropometric Data 59
Longitudinal Study, Performance Data 62
Mental Performance Data, Average Values 69
Mental Performance Data, Training Effects 83
Mental Performance Data, Circadian Rhythms 99
Beta Error 104

Discussion 111

Effects of Age and Sex Differences 113

Effects of Motivation 114

Cross-Sectional Versus Longitudinal Studies 116

Longitudinal Study: Changes in Circadian

Rhythms.................................... 118

Conclusions 120

Appendices 121

References 133

TABLES

Table 1. Anthropometric + Performance Data, Pilot Study.............................. 43

Table 2. ADD2 Speed x Accuracy Product, Pilot Study ... 45

Table 3. LOGI Speed x Accuracy Product, Pilot Study ... 47

Table 4. PAULI Speed x Accuracy Product, Pilot Study .. 49

Table 5. MAST2 Speed x Accuracy Product, Pilot Study .. 51

Table 6. MAST6 Speed x Accuracy Product, Pilot Study .. 53

Table 7. PROBEMEM Speed x Accuracy Product, Pilot Study 55

Table 8. MAT1 + MAT2 Speed x Accuracy Product, Pilot Study 57

Table 9. Anthropometric Data, Longitudinal Study 61

Table 10. Performance Data, Longitudinal Study 63

Table 11. Heart Rate Data, Longitudinal Study 66

Table 12. Maximal Respiratory Quotients Post Exercise .. 67

Table 13. ADD2, Longitudinal Study 70

Table 14. LOGI, Longitudinal Study 71

Table 15. PAULI, Longitudinal Study 72

Table 16. MAT2, Longitudinal Study 73

FIGURES

Figure 1. ADD2, Pilot Study 46

Figure 2. LOGI, Pilot Study 48

FIgure 3. PAULI, Pilot Study 50

Figure 4. MAST2, Pilot Study 52

Figure 5. MAST6, Pilot Study 54

Figure 6. PROBEMEM, Pilot Study 56

Figure 7. MAT1 + MAT2, Pilot Study 58

Figure 8. VO2max vs Time on Treadmill (TOT)........... 64

Figure 9. Respiratory Quotient vs TOT 68

Figure 10. VO2max vs TOT Percent Increase 64

Figure 11. Delta VO2max vs Delta ADD2 75

Figure 12. Delta VO2max vs Delta LOGI 76

Figure 13. Delta VO2max vs Delta PAULI 77

Figure 14. Delta VO2max vs Delta MAT2 78

Figure 15. VO2max vs ADD2 Percent Increase 79

Figure 16. VO2max vs LOGI Percent Increase 80

Figure 17. VO2max vs PAULI Percent Increase 81

Figure 18. VO2max vs MAT2 Percent Increase 82

Figure 19. ADD2 Percent Correct vs Seed Number 84

Figure 20. ADD2 Reaction Time vs Seed Number 85

Figure 21. ADD2 Speed x Accuracy vs Seed Number 86

FIgure 22. LOGI Percent Correct vs Seed Number 88

Figure 23. LOGI Reaction Time vs Seed Number 89

Figure 24. LOGI Speed x Accuracy vs Seed Number 90

Figure 25. PAULI Percent Correct vs Seed Number 92

Figure 26. PAULI Reaction Time vs Seed Number 93

Figure 27. PAULI Speed x Accuracy vs Seed Number 94

Figure 28. MAT2 Percent Correct vs Seed Number 96

Figure 29. MAT2 Reaction Time vs Seed Number 97

Figure 30. MAT2 Speed x Accuracy vs Seed Number 98

Figure 31. ADD2 Speed x Accuracy vs Time 100

Figure 32. LOGI Speed x Accuracy vs Time 101

Figure 33. PAULI Speed x Accuracy vs Time 102

Figure 34. MAT2 Speed x Accuracy vs Time 103

Figure 35. Power vs Size of Detectable Difference for ADD2 107

Figure 36. Power vs Size of Detectable Difference for LOGI 108

Figure 37. Power vs Size of Detectable Difference for PAULI 109

Figure 38. Power vs Size of Detectable Difference for MAT2 110

APPENDICES

Appendix 1. Medical Examination and History 121

Appendix 2. Informed Consent 125

Appendix 3. Instructions, Longitudinal Study 130

Appendix 4. Exercise Log 132

INTRODUCTION

It is now well established that aerobic physical conditioning has a wide variety of physiologically beneficial effects on people. Among other things exercise has been demonstrated to increase maximal cardiac output (Ekblom, 1969), lower blood lipids (Rochelle, 1961), and lower blood pressure (Boyer and Kasch, 1970; Choquette and Ferguson, 1973). However, despite much anecdotal information as to its positive subjective effects (Sheehan, 1980; Vezina and Rebecca, 1980), as pointed out by Folkins and Sime (1981) there are very little reliable data as to the psychological benefits of physical conditioning, especially in normal healthy adults.

In addition to the obvious practical value, quantifying the link between the mind and the body would have many important theoretical consequences. Current theories connecting body with mind are characterized by an almost total lack of supporting data (Folkins and Sime, 1981). For any further advances to be made there must be a base of well-designed, reproducible studies upon which to build.

As shall be demonstrated there are very little reliable data in the literature concerning the effects of physical fitness on mental performance; in fact, there are very little reliable data concerning the effects of physical fitness on any psychological parameter. This introduction will first review briefly the physiological effects of

conditioning, and will then show that under some physiological conditions similar to those accompanying exercise there is an attendant psychological effect. Next, what is known about the psychological effects of exercise will be reviewed, including effects on sleep patterns and circadian rhythms.

Mental Performance

Mental performance is the ability of a person to perform mental tasks. Unlike other psychological parameters such as intelligence, personality or mood, mental performance can be measured unambiguously and yields reliable results that are not dependent upon any specific psychological theory (Kleitman, 1963). Examples of what mental performance tests measure include the ability to add numbers quickly, remember telephone numbers, or recognize patterns embedded in a larger background. Although determining why a person has performed at a given level on a certain mental performance task may be difficult (if not impossible), it is nevertheless possible to determine with precision how well that task was performed. Furthermore, with suitable designs it is possible to determine the effects of other influences (such as drugs or sleep deprivation) on mental performance in an unambiguous way (Buck, 1976; Buck, 1980; Colquoun, 1971; Folkard, 1975; Gutin and DiGennaro, 1968; Kleitman and Jackson, 1950; Kleitman, 1963).

This project is concerned exclusively with determining the effects of physical conditioning on mental performance, but it is neccesary to define some other

psychological parameters, both to further illustrate what mental performance is (and is not), and because much of the literature reviewed in this introduction makes reference to them. For example, while this project does not examine the effects of exercise on mood, other studies showing effects of exercise on mood would at least lay the basis for suspecting effects on mental performance.

Intelligence is defined as the ability to learn or understand from experience, and to use reason in the solving of new problems (Webster, 1978). While intelligence can only be measured by performance tests, it is quite distinct from mental performance in that it involves estimating an abstract internal parameter. Different theories of the nature of intelligence may yield different results when applied to the same test data (Schlesinger and Groves, 1976). As intelligence is defined as an underlying characteristic of an individual, intelligence tests are designed to minimize day-to-day fluctuations and to be relatively independent of environmental influences. In contrast, mental performance tests are sensitive to environmental influences and can vary significantly over time (Colquoun, 1971; Kleitman, 1963).

Personality is the habitual pattern of behaviour of an individual that is thought to be stable with time and relatively insensitive to environmental effects (Schlesinger and Groves, 1976; Webster, 1978). In contrast, mood is the particular state of mind of a person at a given time

(Cattell and Dreger, 1977). Someone with a gloomy personality may be happy at a given time, it is just that this person has a chronic tendency to be gloomy. Personality and mood are measured by asking people questions such as "are you frequently happy" or "are you happy now", respectively. They are not absolute measures, as they depend upon the honesty (or objectivity) of the subject, and also upon the experimenter's definitions. For example, there is no agreement over how many significant dimensions of mood or personality there are, and the behaviourist school of thought holds them to be wholly irrelevent. (Cattell and Dreger, 1977; Schlesinger and Groves, 1976).

Aerobic Versus Anaerobic Exercise

All cellular processes, including those used to power muscular contractions, are driven by the simultaneous degradation of high-energy molecules of adenosine tri-phosphate (ATP). There are two different ways in which cells can make ATP, one of which requires oxygen and one of which does not. The breakdown of glucose to lactic acid does not require oxygen to proceed, and is known as anaerobic metabolism. The complete combustion of glucose to water and carbon dioxide requires oxygen, and is known as aerobic metabolism.

Anaerobic metabolism can produce high power densities in the working muscles, but due to the buildup of lactic acid it cannot be sustained for more than a short time (Gollnick and Hermansen, 1973). Aerobic metabolism cannot produce the high peak power possible with anerobic

metabolism, but it can be sustained for much longer periods of time. For a muscle to exercise aerobically it must be supplied with sufficient oxygen via the blood stream to produce all required ATPs via the tri-carboxylic acid (TCA) cycle. If the supply of oxygen from the blood stream is limited, or the ability of the muscle enzymes to utilize oxygen is exceeded, then the anerobic processes take over and the amount of time that the muscle can work becomes quite limited. It is important to note that both processes can be active at the same time.

Physiology of Aerobic Exercise

In this section we shall briefly review the physiological adaptations to acute aerobic exercise. These adaptations have the effect of increasing the amount of oxygen which can be delivered to, and consumed by, working skeletal muscles. The acute effects of aerobic exercise are distinct from the chronic effects, which will be discussed below.

Before exercise begins or is anticipated there is relatively little blood flow to skeletal muscle. Although the muscles of healthy non-obese adults may constitute over half the body weight, at rest they consume less than 15% of the cardiac output (Mellander and Johanson, 1968). This is due to both tonic sympathetic vasoconstrictor activity and the intrinsic tone of the muscle vasculature itself (i.e. lack of vasodilator metabolites). The heart rate and cardiac output are kept low by both tonic parasympathetic activity and the high resting peripheral resistance

(Robinson et.al., 1953).

At the start of aerobic exercise (or possibly in anticipation of it) parasympathetic activity decreases and sympathetic activity increases (Gasser and Meek, 1914; Vendsalu, 1960). This has several effects upon the circulation and metabolism. The decrease in parasympathetic activity and increase in sympathetic activity causes an increase in heart rate (+ chronotropic) and force of ventricular contraction (+ inotropic) (Tanz, 1967). Vasodilators in the skeletal muscle beds and sympathetic vasoconstrictor activity in the veins of skin and splanchnic regions cause, successively, increased shunting of blood to skeletal muscles, a net decrease in total peripheral resistance, increased return of blood to the heart, and increased cardiac output (Rowall, 1974).

As exercise continues, the increased skeletal muscle blood flow is maintained by metabolic vasodilator products, ensuring that blood is shunted mainly to active muscles with high metabolic demand (Kjellmer, 1965; Skinner and Kostin, 1970). The continued sympathetic vasoconstrictor activity ensures that non-working skeletal muscles and other organs not essential for exercise (skin, viscera, liver) receive relatively little blood. In addition to the increased blood flow, the extraction of oxygen by working skeletal muscle from a given unit of blood may increase from only about thirty percent at rest to nearly eighty percent. The combination of increased blood flow and increased extraction

of oxygen from a given unit of blood may result in an increase in oxygen consumption by more than a factor of 15 (Barcroft and Dornhorst, 1949). In normal healthy adults at sea level, the lungs do not limit oxygen transport, ensuring essentially complete saturation of arterial blood with oxygen (Holmgren and Astrand, 1966).

Physiology of Aerobic Conditioning

In addition to the acute physiological adaptations to aerobic exercise there exists a chronic adaptive response which can further increase one's maximal ability to do aerobic work. The adaptations are primarily cardiovascular and serve to increase a person's maximal oxygen consumption, by increasing maximal cardiac output and maximal extraction of oxygen from blood (a function of skeletal muscle vascularization and enzyme levels). These changes are most evident when a conditioned person is actually exercising. However, the adaptive process causes many changes to occur which persist in the conditioned individual even at rest.

Aerobic physical conditioning occurs when an individual continuously exercises aerobically for a minimum of 15 minutes at least three times a week. A certain minimal sustained intensity is required; it is considered that elevating one's heart rate to from 60 to 90 percent of the heart rate reserve (the difference between resting and maximal heart rate) is optimal (American College of Sports Medicine, 1978).

The training effect can be increased by increasing either frequency or duration or intensity of the exercise periods. However, as the amount of training increases, more and more exercise is required to achieve equal increments of conditioning ("diminishing returns"). It is generally accepted that to achieve a significant training effect and to minimize the risk of injury, a conditioning program should last at least four months (American College of Sports Medicine, 1978). However, significant increases in maximal oxygen consumption can occur in only a few weeks (Saltin and Rowell, 1980). Maintaining a given level of fitness is easier than achieving it, although with total cessation of exercise fitness decreases fairly rapidly (Hickson and Rosenkoetter, 1981).

Effects of Conditioning on the Cardiovascular System

A wide variety of organ systems are affected by chronic aerobic training, most of which are adaptations of the body to endurance exercise. (Some of the changes are not direct adaptations to endurance exercise and may have other effects, which is considered in later sections). The most basic changes are to the circulatory system. The maximal cardiac output increases, due exclusively to an increase in maximal stroke volume (Ekblom, 1969; Ekblom *et al.*, 1968; Thompson *et al.*, 1981b). Also, studies in animals suggest that the maximal ability of working skeletal muscles to extract oxygen from blood is increased, both by increased capillary densities and by increased muscle enzymes (Ekblom

et al., 1968; Holloszy, 1973). There is also an increase in maximum total blood flow to the working muscles (Mackie and Terjung, 1983). Together an increase in maximal blood flow and extraction of oxygen from that blood can increase the ability of a person to consume oxygen (and hence to exercise aerobically) by up to 40 percent over the rate in a completely untrained state (Ekblom *et al.*, 1968).

Effects of Exercise on Sleep

It might be thought that the effects of exercise and conditioning on human sleep would be quite well established by now, for unlike purely subjective psychological measures there exist several unambiguous and easily quantifiable measures of sleep. The response of the cortical electro-encephalogram (EEG) to sleep has been studied quite thoroughly and is easily recorded (Weiner and Goetz, 1981). Total time asleep, sleep latency (time between going to bed and falling asleep), and overall physical motion during sleep can be quite accurately measured. Finally, a person's subjective rating of sleep quality can be evaluated.

Unfortunately there are several problems with the existing literature, and the effects of both acute and chronic exercise on human sleep are still rather poorly understood. Part of the problem is the extreme variablity of human sleep, both between and among subjects, and the problem of comparing sleep in a laboratory setting to sleep under more natural conditions. Also, most of the studies have attempted to define the effects of conditioning by

utilizing groups at pre-exisiting levels of fitness, rather than by following the effects of a conditioning program longitudinally. Finally, little is known about the functions of sleep if any, making it difficult to determine what would be most profitable to study.

Two of the theories of the function of sleep are the restorative theory, in which physical restoration occurs during sleep, especially during slow-wave sleep, and the energy-conservative theory, in which sleep functions to limit the expenditure of calories by restricting the amount of time a person can remain physically active (Trinder et al., 1982). Both theories predict that exercise and conditioning would increase the amount of sleep, and in particular that it would increase the amount of slow-wave sleep (SWS). One study found that while runners had no more SWS than non-runners, they had more total non-REM sleep and a tendency to sleep more with less time required before falling asleep (Walker et al., 1978). Another study found that fit subjects had more SWS than unfit subjects (Collingwood, 1972). Some have found increased total amounts of sleep only in people who were conditioned (Griffin and Trinder, 1978; Montgomery et al., 1982). Increased amounts of SWS and decreased REM sleep following heavy exercise have also been found (Shapiro et al., 1975). Albone (1975) felt that part of the reason for the contradictory nature of the literature is a failure to control for the time of day during which the subjects

exercise. He found increased SWS but only in subjects who exercise late in the day (Albone, 1975). There is also evidence from both animal and human studies that chronically elevated metabolism may increase the frequency of rapid-eye movement sleep (Trinder *et al.*, 1982).

The one study to use a longitudinal conditioning program did seem to indicate that while there may be differences between athletes' and non-athletes' sleep, these differences are pre-existing and persist even in deconditioned athletes (Paxton et al., 1983). The acute effects of exercise on sleep the following night may also depend to some extent upon the level of fitness of a person: when the exercise level is not stressful, sleep is deeper, or at least not disturbed, with increased levels of growth hormones (Adamson *et al.*, 1974). However, if exercise is sufficiently intense, sleep can be disturbed, with increased blood levels of glucocorticoids (Buguet *et al.*, 1980). Finally, when athletes are exercise-deprived, both subjective and objective measures of sleep quality deteriorate, suggesting some sort of withdrawal phenomenon (Baekeland, 1970).

Effects of Exercise on Personality

We consider here only the results of those studies that involved longitudinal conditioning programs, as cross-sectional studies do not answer the problem of cause and effect. In general, studies on adults and teenagers show minimal effects of conditioning on personality (Collingwood,

1972; Kowal *et al*., 1978; Tillman, 1974; Werner and Gottheil, 1966). Of the studies that show positive effects, one did not have a control group (Folkins *et al*., 1972) and the other had a control group that was quite different from the experimental group (Sharp and Reilley, 1975). However, all of the studies on self-concept and self-esteem show positive effects (Collingwood, 1972; Collingwood and Willet, 1971; Hilyer and Mitchell, 1979; Kowal *et al*., 1978). Considering studies on post-myocardial infarction or chronic psychiatric patients, some studies showed no personality effects (Young and Ismail, 1976) and others showed positive effects (Lion, 1978; McPherson *et al*., 1967). Two of these studies also showed positive effects on self-concept (Gary and Dixon, 1972; Lion, 1978).

In conclusion, while classical measures of personality are relatively resistent to change by conditioning, self-concept can be positively influenced. This certainly makes sense, as personality is by definition difficult to change, but it is reasonable that a person's self-concept may be influenced to at least some degree by their actual abilities, and it would be very surprising if the increased physical capacity brought about by exercise should fail to improve self-image.

Effects of Exercise on Mood/Affect

Mood and/or affect is the opposite of personality, being precisely those psychological parameters that are not constant, and which vary with environmental stimuli. Cross-

sectional studies have generally shown that fit people experience less depression and anxiety and more positive feelings of self-concept, but as always this may be due more to the intrinsic differences between exercisers and non-exercisers than to the effects of conditioning (Collingwood and Willet, 1971; Gondola and Tuckman, 1983; Martinek *et al*., 1978; Morgan *et al*., 1970).

Effects of Exercise on Mental Performance

The effects of acute exercise upon mental performance are confusing, with some studies showing increases and others showing decreases (McGlynn *et al*., 1979; Spano and Burke, 1976; Vlahov, 1979). This is most frequently hypothesized to be due to a U-shaped relation between overall arousal level and mental performance, with a little stimulation enhancing mental performance and a lot detracting from it (Wojtczak-Jaroszowa, *et al*., 1978). However, it has been determined that an increased level of physical fitness will help improve mental performance during and after a given absolute amount of physical workload (Gutin, 1966; Weingarten, 1973).

Many of the studies on the relation between conditioning and mental performance have been done in children. One study investigated the effects of a motor development program on elementary school students, and found improvements in physical strength, coordination and reading comprehension, although there was no control group (Arnheim and Sinclair, 1974). Another investigated intellectual and

perceptual motor development as a function of a therapeutic play program in maladjusted children, and found significant improvement in performance I.Q. over the control group (Fretz et al., 1969). There were no effects of two different physical education programs on mental performance in first graders (O'Connor, 1974). In a study of 79 children enrolled in a physical developmental program, there was an increase in perceptual and motor skills (Johnson and Fretz, 1967). Finally, a study on the effects of a physical education program on children ages 10-12 years found no effect on I.Q., but did find a positive effect on academic achievement scores (Ismail, 1967). While it should be pointed out that none of these studies is dealing with purely aerobic condi-tioning as we have defined it, the literature does seem to indicate a positive effect of physical conditioning on some aspects of cognitive functioning in children.

In addition to studies on children, there have also been many studies on geriatric and/or psychiatric patients. Cross-sectional studies on older adults indicate that people who remain physically active as they get older have reaction times similar to young adults, while those who remain sedentary experience significant performance deficits (Sherwood and Selder, 1979; Spirduso, 1975; Spirduso and Phillip, 1978). Of course, it may simply be that those people who do not remain active are intrinsically less healthy than those who do, and that the performance

decrements are due more to some underlying pathology than to physical inactivity. In addition, these studies do not separate cause from effect: do older people remain active because their reaction times are faster or vice-versa or are they both independent attributes of these individuals?

Studies investigating the effects of exercise on institutionalized geriatric psychiatric patients have found significant improvements in cognitive abilities (Powell, 1974; Stamford et al., 1974). One investigation on the effects of physical conditioning on normal older adults found no changes in cognitive abilities (Barry et al., 1966), while another found positive effects (Dustman et al.,1984). Another investigation on the effects of a diet and exercise regimen upon older people suffering from a variety of degenerative diseases did find improvements in mental acuity (Merzbacher, 1979). Barry, Merzbacher, Stamford, and Dustman demonstrated actual changes in fitness levels, and all five (including Powell) of these studies used controls. To sum up, the evidence suggests that physical conditioning improves mental performance in older people, especially those suffering from physical degenerative diseases.

The literature is much sparser when dealing with studies on normal healthy adults. Cross-sectional studies which compare sedentary people with people who have already chosen to condition themselves are of limited utility when trying to determine the actual effects of conditioning

alone. The one longitudinal study did find positive effects of conditioning on cognition, and documented an increase in fitness, although there was no control group (Young, 1979).

<u>Effects of Exercise and Conditioning on Circadian Rhythms</u>

The term "circadian rhythm" was invented by Franz Halberg and refers to cyclic variations in biological processes with a period of approximately 24 hours in length (Halberg, 1969). There is strong evidence for the existence of cyclic variations both longer than 24 hours ("infradian" rhythms, such as weekly, monthly, annually, etc.) and shorter than a day ("ultradian" rhythms) such as the 90-minute rhythm in mental performance (Klein and Armitage, 1979). However, this project is concerned only with circadian rhythms and will not discuss these other rhythms further.

The effects of exercise, and especially of chronic exercise and conditioning, upon human circadian rhythms is uncertain. One study compared the free-running circadian rhythms of nine environmentally isolated men during a two-week period of inactivity with their rhythms during a two-week period of heavy exercise, and found no difference in rhythms of wakefulness, sleep, and rectal temperature (Wever, 1979b). Another found that physical work which was continued throughout the day interacted with the circadian rhythms of mental performance in a complex manner that was very difficult to characterize (Wojtczak-Jaroszawa <u>et al</u>., 1978). The effects of training at different times of the

day upon circadian rhythms during exercise have been examined, and no changes in the rhythms of several physiological variables during exercise have been found (Couzelis, 1976). However, this study did not examine the circadian rhythms when the subjects were at rest.

Effects of Physiological Changes on Psychological States

As we have seen, aerobic conditioning has significant physiological effects both acutely and chronically. There is also evidence that aerobic conditioning has significant psychological effects. However, there is as yet no established mechanism that could explain the effects of conditioning upon psychological states. While many of the effects of physical conditioning are primarily adaptations to increased sustained physical workloads, this does not mean that other parameters may not be affected. This paper is concerned with the possibility that some of the effects of conditioning may be psychological in nature. While evidence for the linkage of cause and effect between physical conditioning and psychological changes is not well delineated, many of the physiological changes known to be caused by conditioning have also been shown to have psychological effects under at least some conditions. Thus while little is presently known about the psychological effects of exercise there do exist plausible mechanisms. The next few sections deal with physiological parameters affected by conditioning that have been independently demonstrated to have psychological effects.

Thyroid Hormones

There is presently little consensus as to what, if any, the effects of exercise are on thyroid hormones, although some studies have shown effects. Terjung and Winder (1975) have reviewed this area, and while they concluded that the blood levels of thyroid hormones were unaffected by conditioning they did find evidence that turnover ("utilization") rates of thyroid hormones may be increased. A more recent study found significant increases in T4 (thyroxine), rT3 (reverse- triiodothyronine) and TSH (thyroid stimulating hormone), and decreases in the T4/rT3 and T3/rT3 ratios in women who were trained to the point where they were running 80 kilometers per week (Boyden et al., 1984). This is thought to reflect an increased thyroid hormone metabolism.

Pathological changes in thyroid hormone metabolism can produce dramatic psychological effects, with excesses causing nervousness, anxiety or hyperactivity, and deficits causing apathy and slowing of intellectual activity (Isselbacher et al., 1980). Thyroid hormone receptors have been identified in the brain, and thyroid hormone metabolism has also been found in the brain (Crantz and Larsen, 1980; Schwartz and Oppenheimer, 1978). Finally, in a cross-sectional study of 69 normal university students, significant negative correlations were found between serum T3 and cognitive performance, although in the male subjects there was a positive correlation between levels of T3 and

speed on a word fluency task (Tucker _et al._, 1984).

Central Amines

Most of the experiments on the effects of conditioning on amines (dopamine, serotonin, norepinephrine) in the central nervous system have been on rats and mice, and have indicated that exercise causes increases in central amines at least acutely if not chronically. It has been found that exercising rats caused increased synthesis of brain norepinephrine (Gordon et al., 1966). Eight weeks of chronic exercise caused increased levels of brain norepinephrine and serotonin (except for the cerebral cortex, where serotonin levels were lower) (Brown et al., 1979). Exercise has also been found to cause acute increases in brain dopamine metabolism (Bliss and Ailon, 1971). Finally, it has been found that exercise can cause an increase in serotonin and norepinephrine (Barchas and Freedman, 1963).

The psychological effects of the central amines, which act as neurotransmitters in various brain nuclei, are potentially profound. The role of striatal dopamine deficiency in the etiology of Parkinson's disease is now well established (Yahr, 1975). Central amines are also thought to play a strong role in the pathogenesis of both depression and mania. It has been observed that clinically depressed patients have low levels of amine metabolites in both urine and cerebrospinal fluid, which implies a general reduction in activity or metabolism of amines (Bond _et al._, 1972; Coppen _et al._, 1972; Fawcett _et al._, 1972; McLeod and

McLeod, 1972; Papeschi and McClure, 1971; Roos and Sjostrom, 1969). Conversely, manic patients may have elevated levels of urinary amine metabolites (Bond *et al.*, 1972; Fawcett *et al.*, 1972; Jones *et al.*, 1973). Both the mono-amine oxidase inhibitors, (which inhibit the degradation of norepinephrine), and the tricyclics, (which block re-uptake and thus increase extracellular levels of norepinephrine), are effective anti-depressant agents (Goodman *et al.*, 1980). The anti-hypertensive drug reserpine, which depletes stores of catecholamines and serotonin centrally, can have depression as a major side effect (Goodman *et al.*, 1980). Ransford has reviewed this field, and has proposed that exercise may exert an anti-depressent effect through alterations in central amines (Ransford, 1982).

Endorphins

Recently evidence has accumulated that physical exercise increases blood levels of endorphins. Many studies have shown increases in serum concentrations of beta-endorphins acutely after heavy exercise (Borz *et al.*, 1981; Fraoli *et al.*, 1980; Janal *et al.*, 1984; Mauser and Reynolds, 1977). However, it remains to be seen whether or not a rise in plasma beta-endorphins has any significant psychological effects. In studies where the opiate-antagonist drug naloxone was given to block the effects of beta-endorphins, some demonstrated a positive psychological effect for endorphins (Tucker *et al.*, 1984) and some found no effect (Appenzeller *et al.*, 1980).

The psychological actions of injected exogenous endorphins are similar to the actions of opioid drugs (endorphin = 'morphine within'), causing analgesia, drowsiness, changes in mood and clouding of mental processes (Goodman *et al*., 1980). Nevertheless, the role of naturally occurring endorphins, especially in the general circulation outside of the central nervous system, is still unclear (Goodman *et al*., 1980).

Testosterone

There is evidence that physical exercise can increase levels of testosterone and related androgens. One study investigated the effects of five days of exercise, and found significantly elevated plasma testosterone levels in the subjects even when they were at rest (McConnel and Sinning, 1984).

Many studies have demonstrated a correlation between serum levels of testosterone in males and aggressive behavior. In one study on hockey players, there was a significant correlation between the degree of aggressive response to threat and serum testosterone (Scaramella and Brown, 1978). Studies on criminal populations have also demonstrated correlations between aggressiveness and serum testosterone (Kreuz and Rose, 1972; Rada *et al*., 1976). It has also been demonstrated that men with the type-A personality trait have elevated daytime levels of urinary testosterone glucuronide, which is indicative of increased testosterone biosynthesis or turnover rate (Zumoff *et al*., 1984).

Effects of Circadian Rhythms on Mental Performance

The purpose of this project was to determine not only the effects of physical conditioning upon baseline mental performance, but also the effects on the circadian rhythms of mental performance. For example, it is possible that conditioning might not have any effect upon an individual's performance at ten AM but might still have effects at 12 Midnight. It is important, therefore, to review the literature concerning circadian changes in mental performance and how conditioning may impact upon this rhythmic variation.

Under well-controlled conditions Kleitman demonstrated that human mental performance shows a rise in the morning and fall in the late evening, and they also demonstrated that the rhythms in mental performance are strongly correlated with body temperature (Kleitman, 1933; Kleitman and Jackson, 1950). They concluded that it is the rise in body temperature caused by increases in muscular activity and metabolism that is responsible for this (Kleitman, 1963). However, later work has shown that this cannot be the whole story, for while body temperature typically shows a single peak during the day, performance often shows two peaks separated by a mid-afternoon dip (Colquoun, 1971). There are also many pathological cases in which the rhythm of body temperature becomes disassociated from the rhythm of sleep and wakefulness (Colquoun, 1971).

Since the time of Kleitman, much of the work on the

circadian rhythm has been influenced by the writings of Franz Halberg. His working hypothesis is that circadian rhythms are not simply a response to the 24-hour cycle of night and day but rather are driven by an endogenous oscillator which, although it may be influenced by the external environment, can nevertheless proceed in the absence of any external stimuli (Halberg, 1969). This is borne out by studies of total environmental isolation, in which people living in deep caves still show circadian rhythms in heart rate, activity patterns, cortisol excretion, etc., of approximately 24 hours, and by studies of bedrest where subjects also continued to show circadian rhythms in the absence of any changes in activity level (Wever, 1979a).

Folkard and his collaborators have shown that performance on many tasks is paradoxically higher in the early morning and early evening hours, with a low point in the midafternoon, and has hypothesized that this is due to differing memory loads (Folkard, 1975; Folkard, 1979a; Folkard, 1979b; Folkard *et al*., 1976; Folkard and Monk, 1979). Thus, the dependence of mental performance upon time of day is more than a simple monotonic rise and fall. Depending upon the design of the task mental performance may show a complex relationship with time.

Finally, it has been shown that stresses such as changes in sleeping hours or 'jet-lag' can adversely affect performance, and can acutely desynchronize one's

circadian rhythm of mental performance (Colquoun, 1971). The ability of people to tolerate this kind of stress is quite variable, although why some people tolerate jet-lag or shift changes better than others is not known (Colquoun, 1971).

Conclusions

In summary, it is now well known that aerobic physical conditioning has widespread effects on many different organ systems, and under at least some conditions it has been demonstrated that changes in some of these systems can significantly affect the psychological state of an individual. Nevertheless, there are few reliable data linking changes in conditioning with psychological changes. Most studies have had one or more serious flaws, such as purely cross-sectional design, no control group, a control group which is unmatched to the experimental group, no control of either type or quantity of exercise, no documented fitness changes, etc. As poor as it is, the data are intriguing, and do suggest some positive effects on mood and self-concept, and positive effects on mental performance in some groups such as school children or geriatric psychiatric patients. There appears to be no effects upon circadian rhythms of mental performance, although this is unclear. Some positive effects on sleep quality may occur with conditioning, although the best study done to date shows no effects.

Specific Aims

The specific aim of this study was to characterize the effect of an aerobic conditioning in normal healthy adults on both baseline and circadian variations in mental performance as measured by a battery of well-defined mental performance tests. The shortcomings of the previous studies were avoided, specifically:

1. The type of exercise and conditioning were monitored and quantified. This study looked only at changes in aerobic conditioning as quantified by a treadmill stress test.
2. Subjects were healthy adults demonstrated to be free from any significant pathology.
3. Subjects were well matched for age, presumed "I.Q." and educational background, and work environment.
4. Subjects were randomly assigned to either a control or an exercise group, and otherwise were treated identically.

Materials and Methods

Overview

The basic design of the experiment consisted of two parts: a cross-sectional pilot study and a definitive longitudinal study. The pilot study consisted of recruiting subjects who had chosen to maintain themselves at different levels of fitness, divided for the purpose of the study into one of three groups: sedentaries who did no regular physical conditioning, joggers who ran between five and 15 miles per week, and marathoners who ran 50 or more miles per week. While cardiovascular fitness can be established and maintained by any of a variety of repetitive exercises requiring multiple large-muscle groups and producing a sustained elevation in heart rate (American College of Sports Medicine, 1978), running is easily quantititated and commonly employed. Consequently, running was chosen to segregate subjects by conditioning. The subjects were tested for aerobic capacity and also for the ability to perform on a wide range of mental performance tests. The subjects were familiarized with the tests and given several practice sessions, then were tested eight times at two hour intervals starting at 0800. The cross-sectional pilot study was done to gain experience with the testing setup, and more importantly to focus the selection of mental performance tests on those that showed the greatest reproducibility, tested distinct functions and appeared to separate conditioning groups.

For the longitudinal study a well-matched group of people were instructed to avoid any regular endurance exercise for a minimum of six weeks. Aerobic fitness declines rapidly without regular exercise and six weeks is more than enough time for deconditioning to occur (Saltin and Rowell, 1980). The subjects were then tested both for aerobic capacity and the ability to perform on selected mental performance tests. The subjects were then randomly assigned to a four-month conditioning program or instructed not to engage in any regular physical activity during the same period. Finally both the test of aerobic capacity and the mental performance tests were repeated on both groups. Assuming that the members of the experimental group actually had significant increases in aerobic capacity and that the members of the control group did not, any changes in mental performance of the exercise group not explainable by similar changes in the control group would thus be due to the increase in aerobic conditioning.

Subjects

Subjects were recruited from the house-staff (interns and residents) at the Walter Reed Army Medical Center ("WRAMC") in Washington, D.C., as they constitute an extremely well-matched population, with similar educational backgrounds and work requirements. All were healthy, non-smokers aged 25 to 37. All subjects completed a medical history questionnaire (Appendix I). All subjects were free of detectable cardiovascular disease as determined by a

medical examination which included a twelve-lead electrocardiogram. Potential subjects with a clinical history or other evidence of medical problems which could limit a maximal exercise performance test were eliminated from the study. This study was conducted with the approval of the human use committee.

While invitations to participate in this study were sent out to over 160 interns and residents, only 35 responded, and of this figure more than half dropped out before the study was completed. Attrition was due to an unwillingness to be randomly assigned to one or the other groups, to a failure to maintain a fitness program or to injury. The final population of subjects who completed all phases of the study consisted of seven control and seven experimental subjects. All but two of the control group were men.

Body Fat Determination

Percent body fat was determined for all subjects before and after the four-month training period by a standard hydrostatic weighing technique. This was performed in a four foot deep by six foot in diameter tank using a chair suspended from a Chatillon 15 kg scale. Subjects forcefully exhaled as much air as possible until three consistent readings were obtained. Residual volumes were estimated from a standardized chart. The body density was calculated by the following formula:

$$D = \frac{Wa}{\frac{(Wa - Ww)}{Tc} - RV}$$

D = Density
Wa = Weight in air in Kg
Ww = Weight totally submerged in water in kg
Tc = Correction factor for temperature of water
RV = Estimated residual volume in liters

Percent body fat was then calculated according to the following formula (Siri, 1961):

$$\%Fat = 495/D - 450$$

Exercise Testing Protocol

The single best indicator of a change in aerobic conditioning is a change in the maximal oxygen consumption with exercise, or VO2 max. A previous study has demonstrated high reliability and sensitivity of measures of VO2 max to conditioning effects in longitudinal studies, as well as a high degree of insensitivity to technique or effort (Taylor *et al.*, 1955).

The subjects were told to fast and avoid drinking any caffeinated beverages for at least eight hours prior to the exercise test. Subjects rested for several minutes in a reclining chair until their respiratory quotient (ratio of CO_2 production over O_2 consumption) stabilized at or below 0.8. Subjects were then exercised on a treadmill according to the Bruce protocol (Bruce *et al.*, 1963). On this protocol treadmill speed and grade increased in three minute stages.

The speeds and grades are as follows:

Stage	Speed(MPH)	Grade(%)
1	1.7	10
2	2.5	12
3	3.4	14
4	4.2	16
5	5.0	18
6	5.5	20

Electrocardiograms were monitored on each subject before, during and after exercise with a 12-lead Quinton Instrument model 633 (Quinton Instruments, Washington). Pre-gelled electrodes were placed on dry skin previously cleaned with alcohol and painted with benzoin. A Beckman Metabolic Measurement Cart, or MMC, (Beckman Instruments, Illinois) was used to analyze and record oxygen consumption, carbon dioxide production and other cardiorespiratory variables at rest, during exercise, and for twenty minutes after the end of exercise (Beckman, 1979). Heart rate as determined by the Quinton ECG machine was recorded by hand for each period of data collection for the Beckman MMC. Data were collected every 60 seconds during rest and for the first six minutes of exercise, every 30 seconds for the remainder of exercise and the first four minutes of recovery, and again every 60 seconds for the remainder of recovery. The MMC was calibrated before and after each subject was tested and in all cases changes in calibration were less than one percent.

All subjects were encouraged to exercise on the treadmill to exhaustion. Objective criteria for maximal

effort included a plateau in heart rate or oxygen consumption and a respiratory quotient greater than 1.0. As there is evidence that the menstrual cycle does not affect maximal oxygen consumption, this was not controlled for the female subjects (Hall et al., 1981). None of the subjects smoked, eliminating the effect of smoking on maximal oxygen consumption (Montoye et al., 1980).

One control subject severed the tendon to her big toe during the control period and was unable to perform the second treadmill test. Rather than lose a subject it was decided to use a bicycle ergometer for the second exercise stress test, keeping all other aspects of the test unchanged. The bicycle ergometer was set up to attempt to match as closely as possible the workloads at the different stages of the Bruce protocol. It has been shown that the maximal oxygen uptake on a bicycle ergometer is attained at a pedalling rate of 60 revolutions per minute, so the rate was held to a constant 60 R.P.M. throughout the test (Astrand and Saltin, 1961). Changes in workload were effected by changing the resistance of the bicycle ergometer. The subject weighed 53.4 kg, and the mechanical work equivalents in terms of the mass lifted per unit time (Van Ingen Schenau, 1980) for this subject to run the Bruce protocol were 2420, 4170, 6600, 9300, and 12400 $kg \cdot m^2 \cdot sec^{-2}$ for the first five stages. However, running on an incline requires considerably more energy expenditure than is indicated by the mass lifted, and on the basis of other

studies it was decided to double the work settings of the bicycle (Bobbert, 1960a; Bobbert, 1960b; McKay and Banister, 1976). Specifically, within the range of speed and grade used in the Bruce protocol, these data indicate that approximately twice as much work is performed by a person running on a treadmill than would be predicted by the mass lifted times the distance lifted per unit time. Finally, the maximum oxygen consumption that can be obtained on a bicycle is typically seven percent less than that obtained on a treadmill, and the final value was multiplied by 100/93 before performing statistics. Although the subject's time on the bicycle test was comparable to the initial treadmill run, the final time was left out of the calculations as there was no basis for comparison.

Mental Performance Tests

The mental Performance Assessment Battery (PAB) was developed by the Department of Military Medical Psychophysiology at the Walter Reed Army Institute of Research (WRAIR), Washington D.C. (Thorne et al., 1984). The PAB is written in the BASIC programming language and runs on a modified Apple II microcomputer. The computer runs all the subtests automatically, and also records all subject responses including reaction times to the nearest 10 milliseconds. Data are recorded on floppy disks and printed out as the test progresses, so that test data are always recorded on two different media and it is unlikely that any data might be lost. A further advantage of printing the

data out is that examination of the printed output yields a check that the subjects performed the tests in the order and at the times prescribed. For each test session, the subject is prompted for the time and date, which is then recorded both on the floppy disk and on the printer. If any of these data had been falsified it would have been very simple to detect by examining the results of the tests performed before and after the test in question. For example, if a subject incorrectly entered the time as 2400 hours when it was in fact 1200 hours, this would have been picked up by noting that the following tests (done by other subjects) were at times prior to 2400 hours.

The computer was set up in a quiet room in the Walter Reed Army Medical Center where the subjects worked. Subjects were briefed on the operation of the computer before the experiment, and were responsible for letting themselves into the room and running the experiment themselves. Instructions were displayed on the wall behind the computer (See appendix II). To start the test the subject simply inserted the floppy disk with his/her name on it into the computer and turned on the power, and the test ran automatically from there. The test was extremely simple to run, and none of the subjects had any trouble operating it.

All subjects initially performed three 'practice' runs of the PAB to learn the details of the individual tests and to get most of the practice effect out of the way. For the three practice runs, feedback was given on a trial-by-

trial basis to speed up the learning process. The subjects were then required to perform ten sessions without trial-by-trial feedback, and to perform them at specified times of the day in a specified order. The times started at 6 in the morning and ended at 12 midnight. Each subject had a card with these ten times on it in a random order, and had to perform the tests in the specified order. Thus, one subject might have to do the tests at 0600, 1400, 2200, 1600, 1800, 0800, 1000, 2000, 2400, and 1200 hours in this order. The purpose of this was to facilitate separating out any residual learning effects from the time of day, so that the effects of the time of day could also be measured. These ten sessions had to be completed before the conditioning program began. After the conditioning program was over, the subjects had to do another 'practice' test, and then another ten sessions also at different times of the day.

The PAB uses a pseudo-random number generator to randomize the tests for each run. As a consequence, for any test, each subject will never be asked to perform the same tasks in the same order on different tests, and will not be able to predict specific questions in advance. However, because the pseudo-random sequence is well defined and repeatable, all subjects were presented with exactly the same tasks on each successive instance of the PAB.

The Performance Assessment Battery used in this experiment was a subset of the full PAB used at WRAIR, using only four of the original eight tests (Thorne *et al.*, 1984).

The tests were ADD2, a two-digit five-number addition task; PAULI, a single-digit addition task; LOGI, a logical decision task; and MAT2, a test of spatial short-term memory.

ADD2

In this test, a column of five two-digit numbers is displayed on the computer screen. The subject's job is to compute the sum of these five numbers, and type in the (usually) three-digit result. There is no set number of trials for this experiment; the subject does as many trials as possible in a two-minute period. All arithmetic had to be done mentally. Paper, pencils or calculators were not allowed. The column of numbers was erased from the computer screen when the subject began typing in the answer, so the subject had to have decided on a complete answer before typing.

PAULI

This test is a single digit addition/subtraction task with reaction times typically a second or less. A single digit from zero to nine is flashed in the center of the computer screen, erased, another single digit is displayed and erased, and then either the plus (+) or minus (-) sign is displayed. The subject must perform the indicated operation on the two digits and type in the single digit answer. If the answer is a two-digit number, only the last digit is typed, and if the answer is a negative number, the subject adds +10 to the result before typing the answer. There is

no time limit for this test. Each experimental run consists of exactly 50 trials.

LOGI

This is a computerized version of a reasoning test based on grammatical transformation (Baddeley, 1968). A sentence appears on the computer screen describing the relative order of the letters A and B, followed by the actual letters A and B. The subject's job is to determine if the sentence correctly describes the relative order of the letters, so for "A follows B   BA" the subject would respond by typing "S" (for "same" or true), and for "B does not precede A   BA" the subject would type "D" (for "different" or false). There are four different sentences (follows, precedes, is followed by, is preceded by), the sentence can be made negative, the order of A and B in the sentence can be swapped, and the order of A and B to the right can be swapped. Thus there are exactly 32 different permutations, and the test procedes through all of them. The test averages two to three minutes a session.

MAT1 and MAT2

In these tests a pattern of stars (*) is displayed in a random pattern on the screen, erased, and after a two-second time delay, either exactly the same pattern of stars or the same pattern with two stars moved is displayed. The subject's task is to determine if the second pattern is the same as or different from the first pattern. Each run consists of ten trials. MAT1 is easier than MAT2, as the

second pattern has more differences from the first on this test. Nevertheless it was quickly discovered that performance on both MAT1 and MAT2 was almost always identical, and for the longitudinal study only MAT2 was used.

PROBEMEM

On this test a horizontal string of nine random numbers, with any given digit not appearing more than twice, was presented for one second and then erased. After a delay of three seconds eight of the original numbers were redisplayed in randomized order, and the subject's task was to type in the single missing digit. As there were no significant differences between the sedentaries and the joggers in the pilot study, this test was not included in the longitudinal study.

MAST2 and MAST6

These tasks were developed by Folkard (Folkard *et al.*, 1976) A row of either two letters (MAST2) or six letters (MAST6) was presented at the top of the screen, and a row of twenty letters was presented in the middle. The subject's task was to determine if all of the letters in the top row were contained in the middle row. As there were no significant differences between sedentaries and joggers on either of these tests for the pilot cross-sectional study, they were both left out of the longitudinal study.

PAB Scoring

In addition to examining percent correct and average reaction times for all subtests, a composite speed x

accuracy product was computed. For ADD2 this consisted of the percent correct divided by the average reaction time. As random guessing would yield a score of 50 percent correct for LOGI, MAST2, MAST6, MAT1, and MAT2, a correction was made in which 50% was first subtracted from the percent correct, before the reaction time division was performed. For PAULI and PROBEMEM the percent correct minus ten divided by the average reaction time was used. Thus, increasing percent correct or decreasing average reaction time will increase the speed x accuracy product, but on the average, random guessing will result in a score of zero.

<u>Conditioning Program</u>

A standardized algorithm developed by the Department of Physical Medicine and Rehabilitation at WRAMC was used to determine the exercise prescriptions for all members of the exercise group. Data from the initial treadmill test and the determination of percent body fat were used to determine the initial prescription. Each subject started out with zero 'points', and was then assigned more points on the basis of maximal oxygen consumption and percent body fat. The algorithm is as follows: Set the variable N=0.

Maximal Oxygen Consumption (ml/kg/min):

	Low	Fair	Avg	Good	High
Male	<25	26-32	33-40	41-50	50+
Female	<22	23-29	30-35	36-45	46+
	N=N+1	N=N+2	N=N+3	N=N+4	N=N+5

Percent Body Fat:

	High	Medium	Low
Male	>22%	16-22%	<15%
Female	>27%	21-27%	<21%
	N=N+10	N=N+15	N=N+20

On the basis of the final value of N, the prescription was set up with those scoring N of 17 or less exercising at 70 percent of maximal heart rate three times a week starting at only 10 minutes at a time, and progressing to 15 and finally 20 minutes. Those subjects scoring N of 18-22 were instructed to exercise at 75% of their maximal heart rate three times a week starting at 15 minutes at a time, and progressing to 20 and finally 25 minutes each time. Lastly, those scoring 23 or above exercised at 80% of maximal heart rate three times a week for 20, 25 and finally 30 minutes a time. Subjects were requested to keep an exercise log where they recorded the days they exercised, the type of exercise, duration, and pulse rates (see Appendix IV). The subjects were instructed to check in at the department of Physical Medicine every two weeks, at which time their exercise logs were reviewed. Contact was also maintained with the control subjects during this period to equalize the experimenter attention given to both groups.

The subjects were allowed to use any form of endurance exercise involving large muscle groups such as running, bicycling or rowing. A target heart rate was set as this provided a simple means of insuring that subjects were exercising at a level high enough to cause a condi-

tioning effect, yet not so high that it could not be maintained for an adequate period of time (Hanson *et al.*, 1980). More work is required to attain the same target heart rate as aerobic conditioning increases. Therefore, this technique is instrinsically self-adjusting to each subject's rate of progress.

Statistics

For the cross-sectional study a one-way analysis of variance was used to determine the presence or absence of significant differences in variables of interest among the three groups. Tukey's w-test (Steel and Torrie, 1980) was used to determine which groups were different from each other if the one-way ANOVA first determined that significant differences existed. The same techniques were used in the longitudinal study to determine the differences between the control and exercise groups. To determine the effects of aerobic conditioning, a one-way ANOVA was applied to the changes for the exercise group versus the changes for the control group. In the case of negative results, an analysis of the beta error was performed (Dotson and Kirkendall, 1974). The subject of beta error is covered in more detail in the Results Section.

Results

Pilot Study, Anthropometric Data

The data from the Pilot study show marked physiological differences among the three groups selected. The treadmill test and anthropometric data for the Pilot study are summarized in Table 1. There were a total of 16 subjects: seven sedentaries, six joggers, and three marathoners. A one-way ANOVA was applied to each variable. The three groups differed in age ($P<0.05$) with the marathoners being older than the joggers who were in turn older than the sedentaries. Tukey's w-procedure found all three groups to differ from each other (Steel and Torrie, 1980). Otherwise the subjects were well matched for height, weight and sex (all males). There was a significant difference in VO2max as expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ among the three groups, with the marathoners being the highest and the sedentaries the lowest. There were similar differences among the three groups for time spent on the treadmill. Again, Tukey's w-procedure found all three groups to be distinct from each other (Steel and Torrie, 1980). While there were no statistical differences among the three groups for weight, there was a tendency for the subjects in the higher fitness categories to be lighter. This resulted in there being no significant differences among the three groups in maximal oxygen consumption as expressed in ml/min. There was also a

tendency for the subjects in the higher fitness groups to have lower maximal heart rates than the sedentaries, but this was not statistically significant at the $P<0.05$ level ($P<0.06$).

TABLE 1

Anthropometric and Performance Data, Pilot Study

	Sedentary	Jogger	Marathoner
n	7	6	3
Age (years)	28.9 | $\pm$6.6	36.5 * $\pm$3.8	44.7 *| $\pm$9.1
Weight (kg)	79.3 $\pm$9.2	77.4 $\pm$14.7	65.4 $\pm$4.8
Height (cm)	181 $\pm$6.9	176 $\pm$8.9	173 $\pm$2.7
VO2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	42.6 | $\pm$4.5	47.0 * $\pm$3.9	59.0 *| $\pm$4.3
VO2max absolute (ml/min)	3404 $\pm$529	3605 $\pm$418	3853 $\pm$306
Time (min)	12.3 | $\pm$1.1	13.1 * $\pm$0.2	17.4 *| $\pm$2.1
HRmax (BPM)	192.9 $\pm$10.6	178.8 $\pm$10.3	184.3 $\pm$2.1

TABLE 1. Anthropometric and performance data on the cross-sectional pilot study. VO2max is the maximal oxygen consumption in $ml \cdot kg^{-1} \cdot min^{-1}$, VO2 is the maximal oxygen consumption uncorrected for the subject's weight in ml/min, Time is how long the subject stayed on the treadmill, and HRmax is the maximum heart rate in beats/minute. Values are $\pm$ standard deviations. The variables age, VO2max and time showed statistically significant differences by one-way ANOVA. Starred variables were judged different from the sedentary and variables with a | were judged different from the joggers by Tukey's w-procedure (Steel and Torrie, 1980). There was a trend for maximal heart rates to be different, but these did not attain statistical significance (P<0.06).

Pilot Study, Mental Performance Data

The mental performance data for the Pilot cross-sectional study indicate a strong correlation between scores on some of the measures of mental performance and the pre-existing level of physical fitness (see Tables two through eight and Figures one through seven). In general, with the exception of performance on the spatial pattern-recognition tasks, the marathoners always performed more poorly than either the joggers or the sedentaries. There were differences between the joggers and sedentaries on ADD2 (two-digit addition), and on LOGI (logical decision making). It was discovered that performance on the two spatial tasks was essentially identical, so only the mean of the two tasks has been summarized here. Statistics were done on the averages across all times by one-way ANOVA, and differences among the three groups were determined by Tukey's w-procedure (Steel and Torrie, 1980). A two-way ANOVA was not done on these data as successive trials were not statistically independent. However, it was noted that for the ADD2 data the joggers and sedentaries performed equally well up until 1200 hours, after which time the performance of the joggers was maintained and the performance of the sedentaries declined.

TABLE 2

ADD2 Speed x Accuracy Product, Pilot Study

TIME	n	Sedentary 7	Jogger 6	Marathoner 3
0800		5.75 ±0.17	6.39 ±0.67	2.83 ±0.40
1000		6.17 ±0.49	7.28 ±1.37	2.0 ±0.56
1200		7.70 ±0.38	8.70 ±1.02	3.38 ±0.31
1400		6.22 ±0.51	8.75 ±0.91	3.71 ±0.82
1600		6.97 ±0.40	8.51 ±0.45	3.83 ±0.53
1800		5.98 ±0.47	8.17 ±0.92	4.09 ±0.37
2000		6.17 ±0.36	8.24 ±0.62	3.93 ±0.73
2200		6.43 ±0.66	8.28 ±1.19	4.67 ±0.54
Average:		6.42 ±0.43	8.04 ±0.89	3.55 ±0.53

TABLE 2. ADD2 (two-digit addition) speed x accuracy product for the pilot study. Values are means ± standard errors of the means. One way ANOVA on the average data showed significant differences ($P<0.05$), with Tukey's w-procedure showing all three groups to be distinct.

FIGURE 1

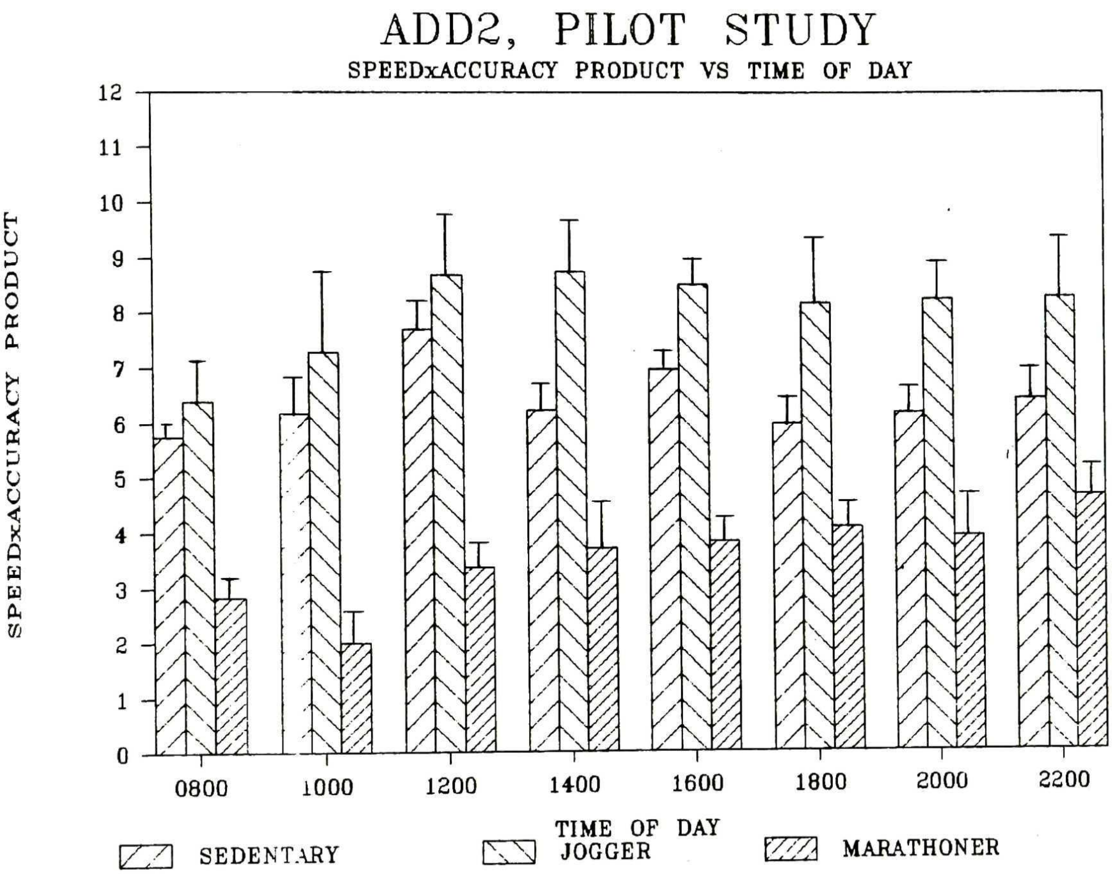


FIGURE 1. Speed x Accuracy product versus time of day for the pilot study, ADD2 (two-digit addition). Error bars are standard error of the mean. One way ANOVA on the average data showed significant differences (P<0.05), with Tukey's w-procedure showing all three groups to be distinct.

TABLE 3

LOGI Speed x Accuracy Product, Pilot Study

TIME	Sedentary	Jogger	Marathoner
n	7	6	3
0800	13.24 ±4.20	12.74 ±1.36	7.53 ±1.01
1000	12.15 ±2.14	15.19 ±2.42	6.89 ±1.19
1200	12.22 ±1.96	15.55 ±1.52	8.11 ±0.95
1400	12.70 ±2.32	16.39 ±2.00	8.20 ±0.56
1600	10.65 ±1.95	15.01 ±1.92	7.83 ±0.67
1800	12.69 ±1.58	15.92 ±1.55	8.89 ±1.39
2000	13.30 ±2.74	15.95 ±1.65	8.89 ±2.31
2200	13.96 ±2.85	15.59 ±1.49	8.13 ±1.46
Average:	12.61 ±2.47	15.29 ±1.73	8.06 ±1.19

TABLE 3. LOGI (logical decision making) speed x accuracy product for the pilot study. Values are means ± standard errors of the means. One way ANOVA on the average data showed significant differences ($P<0.05$), with Tukey's w-procedure showing all three groups to be distinct.

FIGURE 2

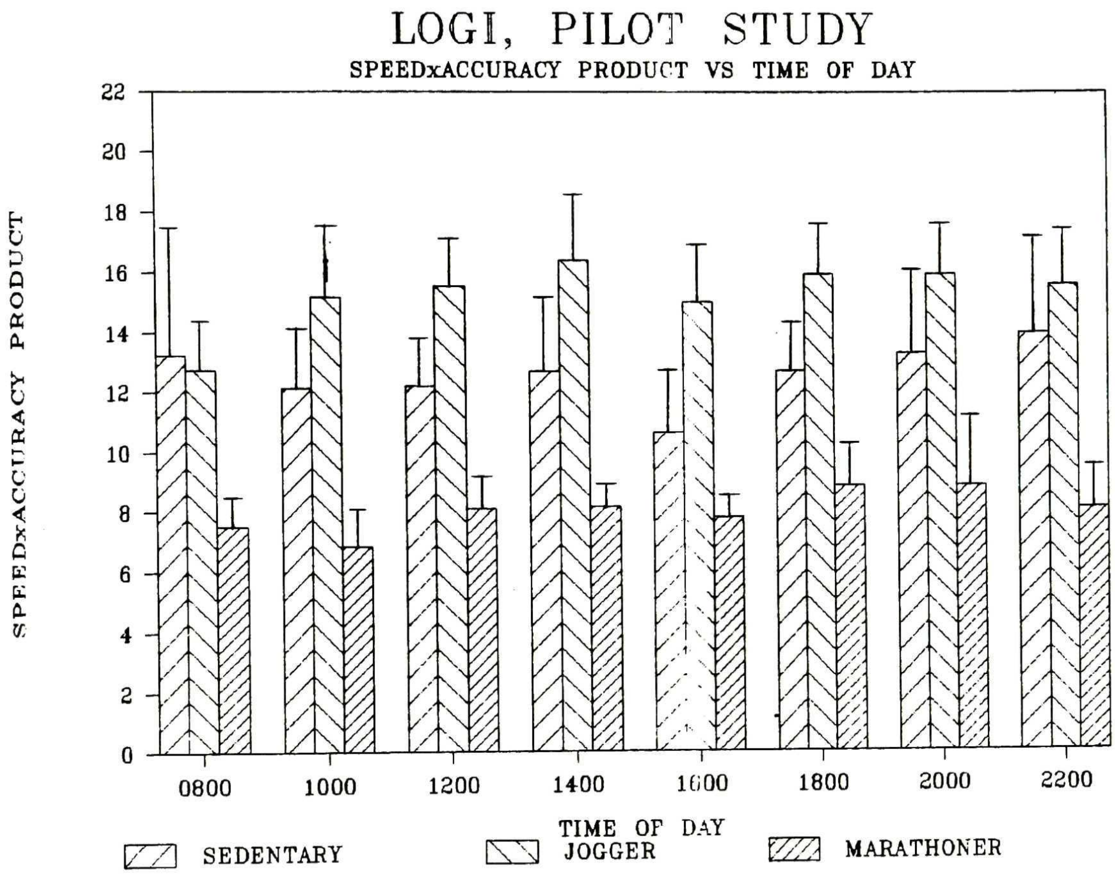


FIGURE 2. Speed x Accuracy product versus time of day for the pilot study, LOGI (logical decision making). Error bars are standard error of the mean. One way ANOVA on the average data showed significant differences (P<0.05), with Tukey's w-procedure showing all three groups to be distinct.

TABLE 4

PAULI Speed x Accuracy Product, Pilot Study

TIME	Sedentary n 7	Jogger 6	Marathoner 3
0800	74.47 ±4.90	76.05 ±8.97	37.75 ±12.4
1000	85.85 ±4.59	92.79 ±13.57	47.86 ±15.45
1200	99.20 ±9.09	90.41 ±9.56	49.91 ±20.45
1400	85.06 ±7.45	83.00 ±9.20	54.44 ±14.68
1600	90.47 ±6.97	91.83 ±9.93	61.88 ±21.65
1800	89.81 ±5.74	95.02 ±8.00	62.69 ±17.14
2000	83.78 ±7.48	90.07 ±6.31	64.44 ±20.40
2200	90.79 ±6.04	88.04 ±5.51	58.80 ±18.42
Average:	87.43 ±6.53	88.40 ±8.88	54.72 ±17.57

TABLE 4. PAULI (single-digit addition) speed x accuracy product for the pilot study. Values are means ± standard errors of the means. One way ANOVA on the average data showed significant differences ($P<0.05$), with Tukey's w-procedure showing the marathoner group to be distinct from the other two groups, but with no statistical difference between the sedentary and jogger groups.

FIGURE 3

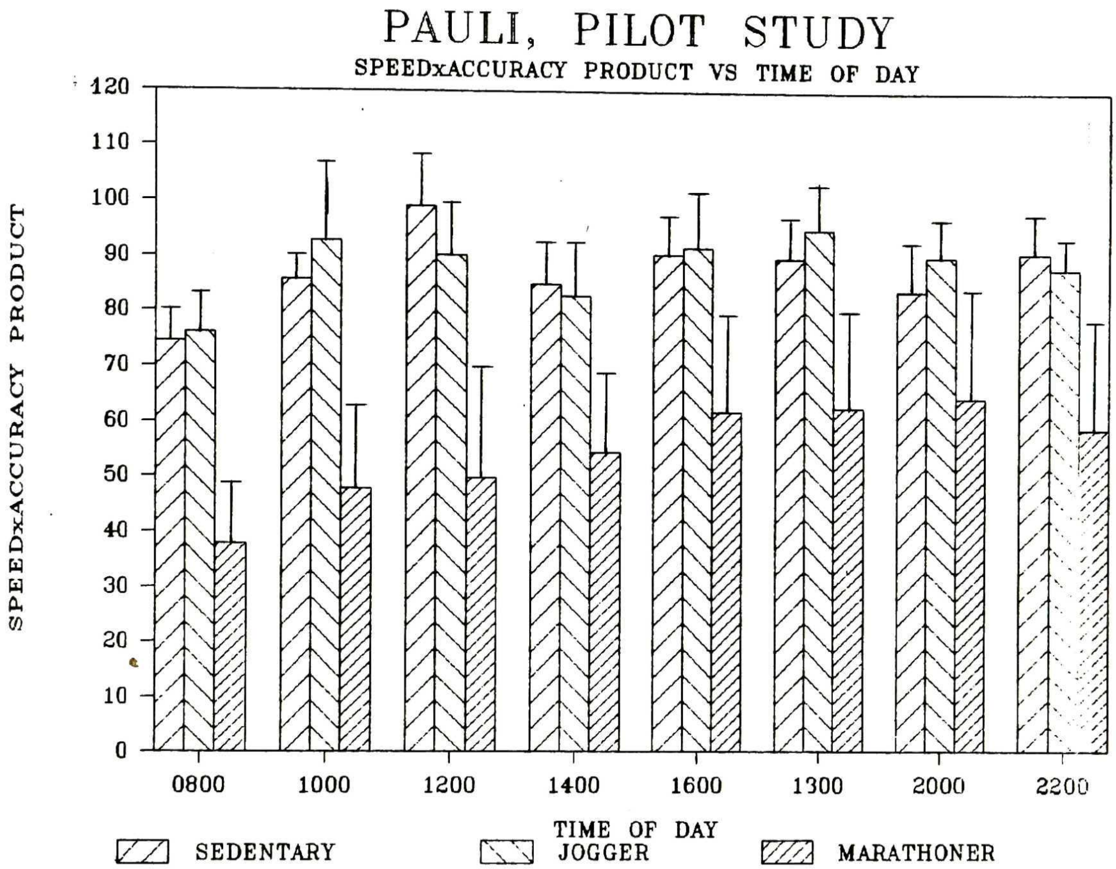


FIGURE 3. Speed x accuracy product versus time of day for the pilot study, PAULI (single-digit addition). Error bars are standard error of the mean. One way ANOVA on the average data showed significant differences (P<0.05), with Tukey's w-procedure showing the marathoner group to be distinct from the other two groups, but with no statistical difference between the sedentary and jogger groups.

TABLE 5

MAST2 Speed x Accuracy Product, Pilot Study

TIME	Sedentary	Jogger	Marathoner
n	7	6	3
0800	10.93 ±1.19	11.11 ±0.85	4.10 ±1.00
1000	11.19 ±1.23	11.09 ±0.91	7.03 ±0.57
1200	9.92 ±1.20	11.26 ±1.29	7.24 ±1.00
1400	12.35 ±1.47	13.13 ±0.99	8.09 ±0.34
1600	11.21 ±1.08	12.88 ±0.63	8.53 ±0.72
1800	12.54 ±1.07	12.39 ±0.59	6.71 ±0.60
2000	11.37 ±1.07	12.42 ±0.91	7.84 ±0.23
2200	12.36 ±1.12	11.96 ±0.59	7.13 ±0.57
Average:	11.51 ±1.18	12.03 ±0.84	7.08 ±0.63

TABLE 5. MAST2 (two-letter search) speed x accuracy product for the pilot study. Values are means ± standard errors of the means. One way ANOVA on the average data showed significant differences ($P<0.05$), with Tukey's w-procedure showing the marathoner group to be distinct from the other two groups, but with no statistical difference between the sedentary and jogger groups.

FIGURE 4

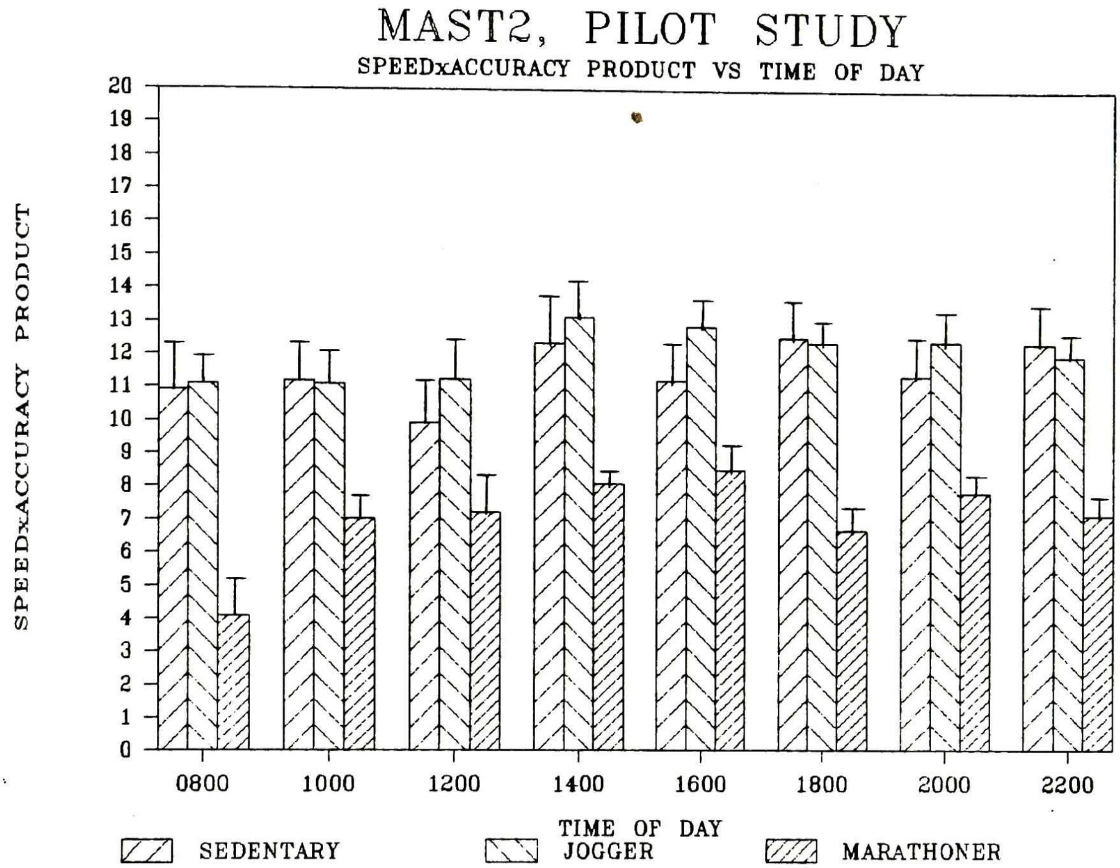


FIGURE 4. Speed x Accuracy product versus time of day for the pilot study, MAST2 (two-letter search). Error bars are standard error of the mean. One way ANOVA on the average data showed significant differences (P<0.05), with Tukey's w-procedure showing the marathoner group to be distinct from the other two groups, but with no statistical difference between the sedentary and jogger groups.

TABLE 6

MAST6 Speed x Accuracy Product, Pilot Study

TIME	Sedentary	Jogger	Marathoner
n	7	6	3
0800	5.53 ±0.53	5.22 ±0.37	3.55 ±0.09
1000	4.77 ±0.67	4.69 ±0.86	3.48 ±0.48
1200	5.02 ±0.38	5.53 ±1.12	3.64 ±0.70
1400	5.93 ±0.72	6.33 ±0.44	4.18 ±0.36
1600	4.95 ±0.33	5.88 ±0.39	4.27 ±0.31
1800	4.27 ±0.37	5.46 ±0.41	3.49 ±0.54
2000	6.08 ±0.82	6.33 ±0.41	4.24 ±0.64
2200	5.95 ±0.84	5.97 ±0.29	3.93 ±0.44
Average:	5.31 ±0.58	5.68 ±0.54	3.84 ±0.44

TABLE 6. MAST6 (six-letter search) speed x accuracy product for the pilot study. Values are means ± standard errors of the means. One way ANOVA on the average data showed significant differences ($P<0.05$), with Tukey's w-procedure showing the marathoner group to be distinct from the other two groups, but with no statistical difference between the sedentary and jogger groups.

FIGURE 5

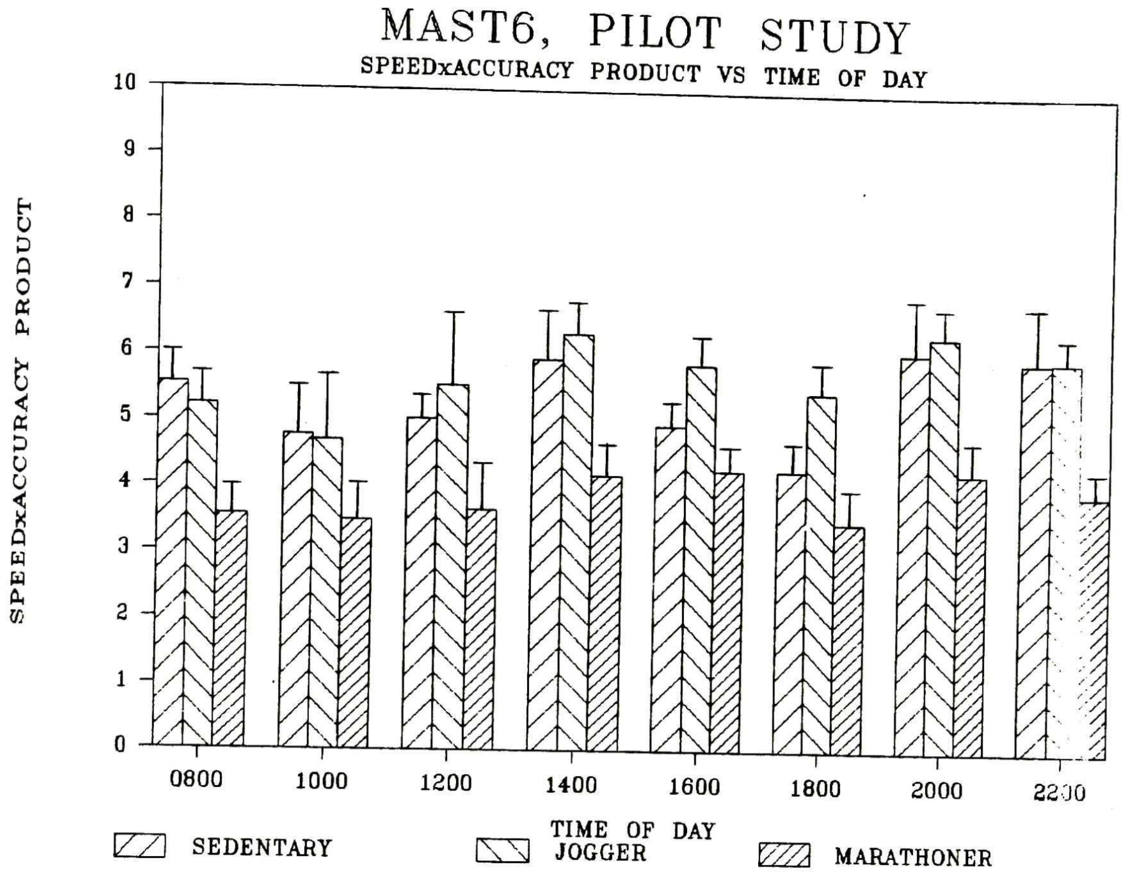


FIGURE 5. Speed x Accuracy product versus time of day for the pilot study, MAST6 (six-letter search). Error bars are standard error of the mean. One way ANOVA on the average data showed significant differences (P<0.05), with Tukey's w-procedure showing the marathoner group to be distinct from the other two groups, but with no statistical difference between the sedentary and jogger groups.

TABLE 7

PROBEMEM Speed x Accuracy Product, Pilot Study

TIME	n	Sedentary 7	Jogger 6	Marathoner 3
0800		7.74 ±1.10	7.73 ±1.63	8.13 ±1.78
1000		10.18 ±1.90	6.59 ±0.74	4.42 ±1.47
1200		10.56 ±4.62	11.81 ±1.68	4.64 ±1.54
1400		11.86 ±2.37	11.12 ±1.74	6.51 ±3.11
1600		9.81 ±1.27	12.52 ±0.88	6.29 ±1.37
1800		12.85 ±1.81	14.26 ±2.48	5.39 ±2.07
2000		9.31 ±1.94	11.06 ±1.03	6.76 ±4.39
2200		11.67 ±2.67	9.95 ±1.03	3.17 ±1.13
Average:		10.50 ±2.21	10.63 ±1.40	5.66 ±2.11

TABLE 7. PROBEMEM (short-term memory) speed x accuracy product for the pilot study. Values are means ± standard errors of the means. One way ANOVA on the average data showed significant differences ($P<0.05$), with Tukey's w-procedure showing the marathoner group to be distinct from the other two groups, but with no statistical difference between the sedentary and jogger groups.

FIGURE 6

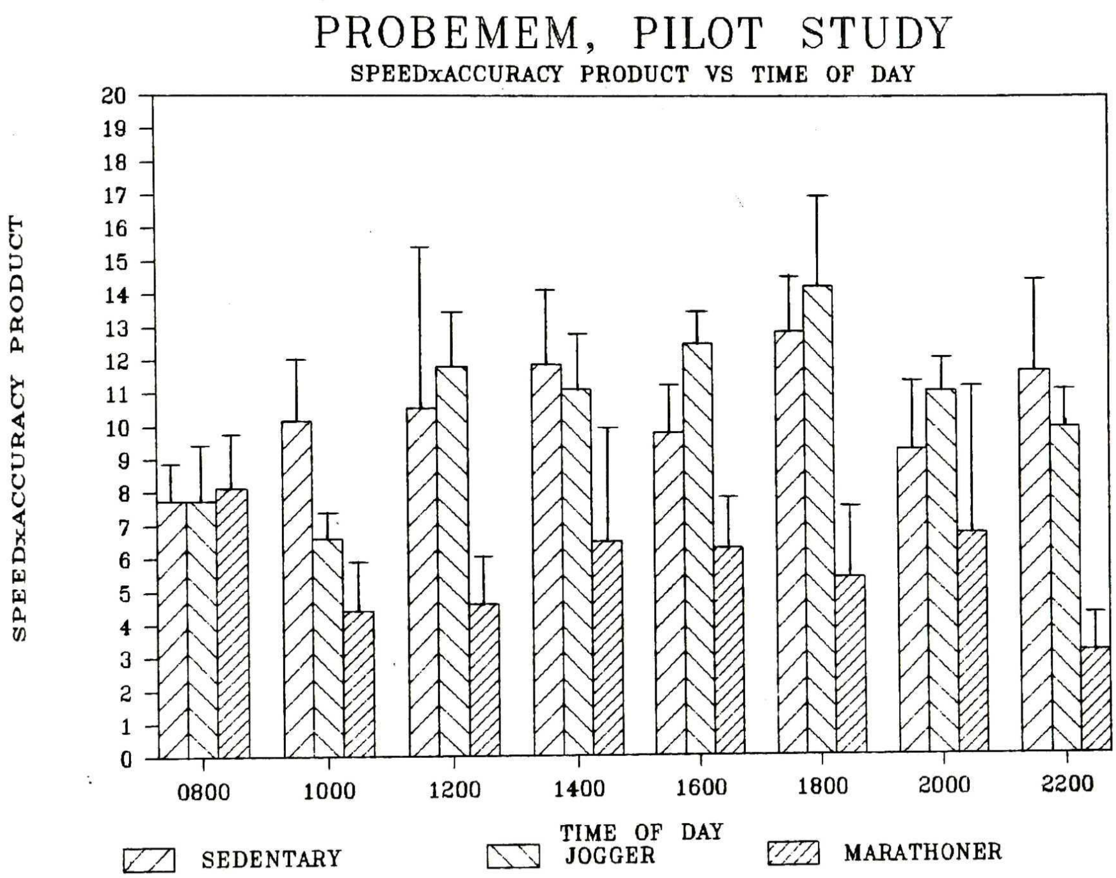


FIGURE 6. Speed x Accuracy product versus time of day for the pilot study, PROBEMEM (short-term memory test). Error bars are standard error of the mean. One way ANOVA on the average data showed significant differences ($P<0.05$), with Tukey's w-procedure showing the marathoner group to be distinct from the other two groups, but with no statistical difference between the sedentary and jogger groups.

TABLE 8

MAT1+MAT2 Speed x Accuracy Product, Pilot Study

TIME	Sedentary	Jogger	Marathoner
n	7	6	3
0800	33.13 ±7.03	30.91 ±9.66	32.08 ±1.89
1000	36.89 ±12.51	36.32 ±9.39	19.00 ±9.89
1200	47.08 ±19.98	63.62 ±15.21	36.60 ±2.97
1400	50.13 ±11.35	55.30 ±13.05	28.12 ±6.56
1600	58.22 ±23.04	46.80 ±15.52	43.05 ±4.48
1800	41.48 ±12.10	30.30 ±8.06	27.12 ±2.24
2000	23.65 ±5.61	24.27 ±10.62	32.72 ±10.74
2200	57.23 ±10.35	48.87 ±6.09	49.15 ±11.70
Average:	43.38 ±12.74	42.05 ±10.95	33.48 ±6.31

TABLE 8. MAT1+MAT2 (pattern recognition) speed x accuracy product for the pilot study. Values are means ± standard errors of the means. One-way ANOVA on the average values showed no significant differences between the three groups ($P>0.05$).

FIGURE 7

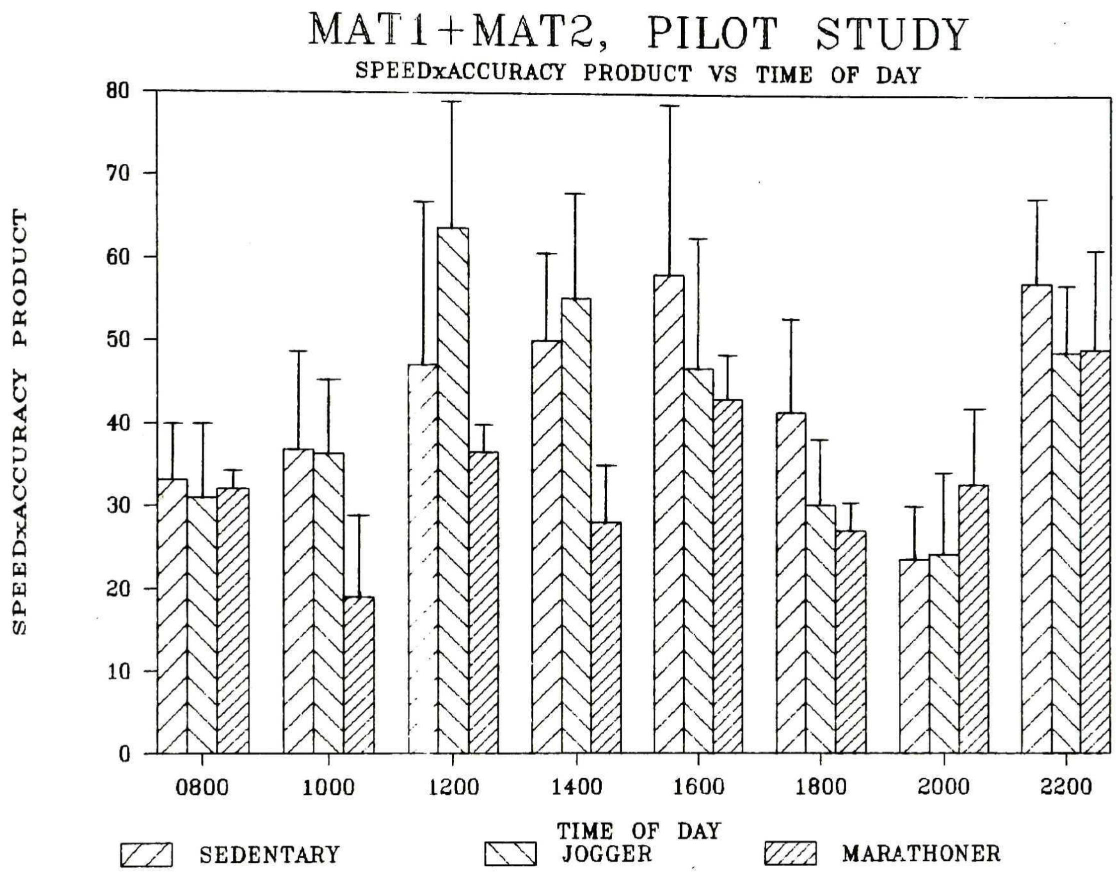


FIGURE 7. Speed x Accuracy product versus time of day for the pilot study, MAT1+MAT2 (pattern-matching test). Error bars are standard error of the mean. One-way ANOVA on the average data showed no significant differences between the three groups.

Longitudinal Study, Anthropometric Data

The anthropometric data for the longitudinal study show that with few exceptions the subjects were well matched for anthropometric variables. These data are summarized in Table 9. Seven of the 14 subjects who finished the entire protocol were in the control group and seven were in the exercise group. Only subjects who completed all phases of the study were included for analysis. Two of the subjects in the control group were female, the rest were males. Of the seven subjects in the exercise group, only four had increases in maximal oxygen consumption as measured by the maximal exercise test. These four subjects are listed separately under the "conditioned" title. Thus the exercise group includes both the four subjects in the conditioned group and the three subjects in the exercise program who did not increase their VO2max.

Statistics for the control vs exercise and control vs conditioned groups were done independently as they constitute two different ways of looking at the data. This study is primarily concerned with the control vs conditioned case, but it is possible that simply being enrolled in a conditioning program may have some effects even if there are no verifiable physiological changes. Note that for the longitudinal study all of the tables have four entries for each variable: Pre, Post, Delta, and %Change. The "Pre" values were taken at the start of the study and the "Post" values at the end, after the four month conditioning (or control)

period had passed. Delta is simply the absolute change that occurred, Post - Pre. The "%Change" is the percent increase that occurred over the Pre value ((100*(Post-Pre))/Pre). As this study is concerned with the longitudinal effects of a conditioning program, most of the emphasis will be placed on analyzing the Delta and %Change. The Pre and Post values are shown primarily to give an indication of the range of the data, and to put any changes that occurred over the four month period into perspective. Delta and %Change are analyzed separately as they again constitute two different ways of considering the data. Statistical significance for one approach will usually, but not always, be mirrored in the other, depending upon how well matched the subjects were for the variable in question.

In general the subjects were well matched for age, height, weight, and percent body fat as measured by underwater weighing. The four subjects in the conditioned group were significantly older than the control group, but the difference between the averages was only 5.18 years. The conditioned group did show a significant drop in weight with respect to the control group during the exercise program, regardless of whether it was measured by simple difference or as a percent decrease. Finally, when compared with the control group the members of both the exercise and the conditioned groups showed significantly lower body fats at the end of the exercise program, but not when this was expressed as a change (either Delta or %Change).

TABLE 9

Anthropometric Data, Longitudinal Study

		Control	Exercise	Conditioned
n		7	7	4
Age, yr		27.6 ±2.5	30.3 ±4.3	32.7 ±3.8 *
Height, cm		171.1 ±10.2	181.0 ±6.7	177.7 ±7.1
Weight, kg	Pre:	66.3 ±13.0	77.0 ±9.6	75.7 ±12.8
	Post:	67.9 ±14.0	77.7 ±10.3	75.0 ±12.6
	Delta:	1.6 ±1.6	0.8 ±2.3	-0.7 ±0.8 *
	%Change:	2.2 ±2.3	0.9 ±2.9	-0.9 ±1.1 *
Body fat, % (hydrostatic)	Pre:	21.6 ±5.8	18.9 ±3.1	19.2 ±3.9
	Post:	24.1 ±3.2	19.3 ±4.7 *	17.9 ±4.8 *
	Delta:	2.5 ±3.3	0.5 ±3.3	-1.3 ±2.7
	%Change:	18.7 ±34.2	2.1 ±16.7	-7.3 ±12.8

TABLE 9. Anthropometric data longitudinal study. Values are means ± standard deviation. *'s denote significance of difference between the control group and either the exercise or the conditioned group, $P<0.05$.

Longitudinal Study, Performance Data

The performance data show that some of the subjects in the exercise group significantly improved their level of aerobic conditioning when compared with the control group. Table 10 summarizes the data for maximal oxygen consumption and time on treadmill. By definition the conditioned group consisted of those subjects who increased their VO2max, and thus it is not surprising that the figures for changes in VO2max were significantly different from the control group, whether expressed as simple difference or percent increase, or as $ml \cdot kg^{-1} \cdot min^{-1}$ or liters/min. The control group showed virtually no change in VO2max over the four-month period (an average of -0.24 percent decrease in $ml \cdot kg^{-1} \cdot min^{-1}$). The conditioned group averaged a 19.39 percent increase in VO2max expressed in $ml \cdot kg^{-1} \cdot min^{-1}$. The conditioned group showed a significant increase in time on treadmill with respect to the control group. Considering the subjects in the exercise group (conditioned and unconditioned) the increases in VO2max of the conditioned group were not sufficient to offset the unconditioned exercisers and, thus, no significant differences in VO2max were observed between the whole group and the control group. The exercise group did show significant increases in time on treadmill with respect to the control group, despite a strong correlation between VO2max and time on treadmill. This relationship holds regardless of whether one examines either absolute or percent changes (See Figure 8).

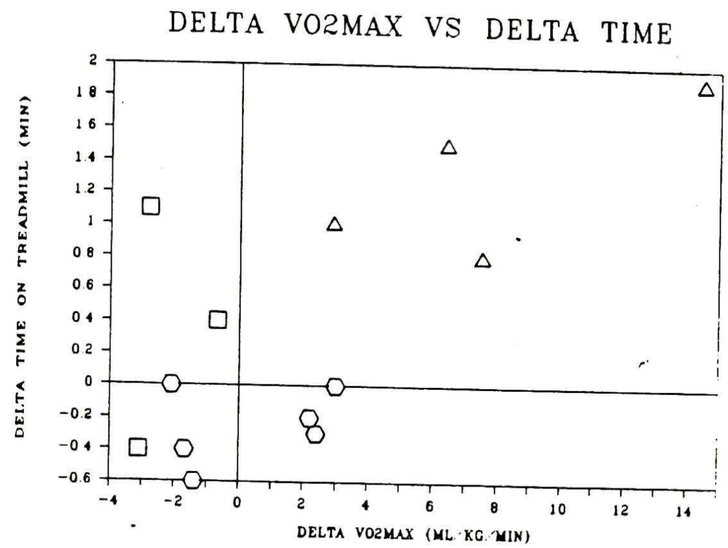
TABLE 10

Performance Data, Longitudinal Study

		Control	Exercise	Conditioned
n		7	7	4
VO2 max, $ml \cdot kg^{-1} \cdot min^{-1}$				
	Pre:	39.7 ±4.9	41.0 ±4.7	40.6 ±6.6
	Post:	39.7 ±4.2	44.6 ±7.8	48.5 * ±8.5
	Delta:	-0.05 ±2.46	3.53 ±6.41	7.83 * ±4.86
	%Change:	-0.24 ±6.01	8.80 ±14.97	19.39 * ±11.20
VO2 max, liters/min				
	Pre:	2.67 ±0.77	3.13 ±0.33	3.04 ±0.40
	Post:	2.72 ±0.74	3.41 * ±0.36	3.56 ±0.30
	Delta:	0.05 ±0.15	0.28 ±0.41	0.53 * ±0.34
	%Change:	2.36 ±6.16	9.61 ±15.04	18.36 * ±14.00
Treadmill, Time, min.	Pre:	11.9 ±1.3	12.7 ±1.0	12.9 ±1.3
	Post:	11.8 ±1.3	13.6 * ±1.3	14.2 * ±1.6
	Delta:	-0.2 ±0.2	0.9 * ±0.7	1.3 * ±0.5
	%Change:	-2.0 ±1.9	7.1 * ±5.6	10.0 * ±3.3

TABLE 10. Performance data, longitudinal study. Values are means ± standard deviation. *'s denote significance of difference from the control group, $P<0.05$.

FIGURE 8 + FIGURE 10



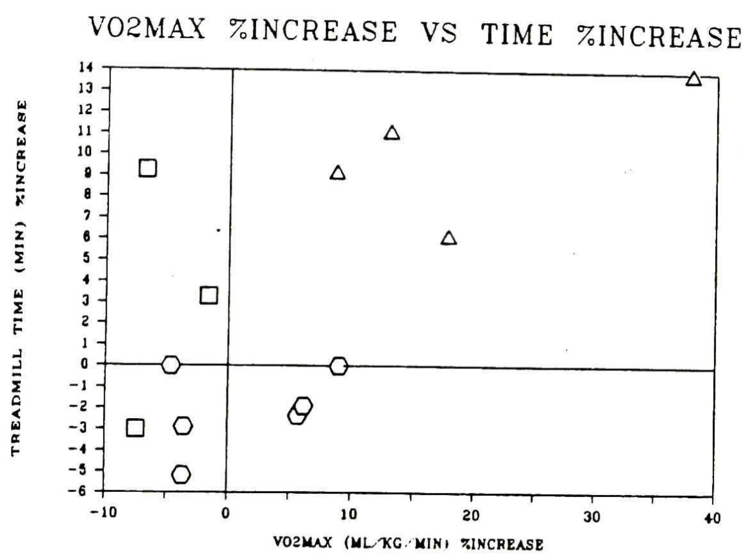


FIGURE 8 + 10. Change in VO2max versus change in time on treadmill. The upper graph is for absolute changes, and the lower graph is for percent changes. Hexagons represent control subjects, triangles represent subjects in the exercise group with increases in VO2max, and squares represent subjects in the exercise group with no increases in VO2max. R = 0.697 for the upper graph and R = 0.641 for the lower graph.

There was no significant effect of conditioning on either maximal heart rate or heart rate 20 minutes after termination of exercise. These data are summarized in Table 11. Maximal heart rate was recorded at the end of the exercise testing protocol, and heart rate 20 minutes post-exercise was recorded while the subject was sitting in a reclining chair recovering. Conditioning may result in slight decreases in maximal heart rates or in an increased rate of recovery of heart rate after the cessation of exercise (Morganroth et.al., 1975) but this was not true of the subjects in this study.

Table 12 shows that the three subjects in the conditioning group who did not increase their VO2max had increases in maximal respiratory quotient (RQ) over the course of the study, when compared with all 11 other subjects in the study. Figure 9 is a plot of the respiratory quotient versus time for these three subjects. The curve for RQ versus time before the conditioning period is superimposed on the curve of RQ versus time after the conditioning period.

TABLE 11

Heart Rate Data, Longitudinal Study

		Control	Exercise	Conditioned
n		7	7	4
Maximal Heart Rate, Beats/min	Pre:	196.0 ±4.8	197.6 ±5.3	195.5 ±4.0
	Post:	195.7 ±6.1	193.0 ±5.9	192.5 ±6.7
	Delta:	-0.3 ±5.3	-4.6 ±5.4	-3.0 ±6.5
	%Change:	-0.1 ±2.7	-2.3 ±2.7	-1.5 ±3.3
Heart Rate 20 min Post Ex.	Pre:	106.9 ±7.9	105.7 ±11.1	104.2 ±12.1
	Post:	105.9 ±9.5	104.9 ±3.3	105.0 ±2.9
	Delta:	-1.0 ±7.7	-0.9 ±10.8	+0.7 ±11.9
	%Change:	-0.8 ±7.3	+0.1 ±10.7	+1.7 ±11.8

TABLE 11. Heart rate data, longitudinal study. Values are means ± standard deviation. *'s denote significance of difference from the control group, $P<0.05$.

TABLE 12

Maximal Respiratory Quotients Post Exercise

	Control	Exercise	Conditioned
n	7	7	4
Maximum RQ:			
Pre:	2.04 ±0.23	1.91 ±0.12	1.88 ±0.13
Post:	1.79 ±0.15	1.90 ±0.27	1.82 ±0.18
Delta:	-0.25 ±0.14	-0.01 ±0.27	-0.06 ±0.13
%Change:	-11.8 ±6.13	-0.43 ±13.84	-3.31 ±6.86

	Unconditioned	All Others
n	3	11
Pre:	1.95 ±0.09	1.98 ±0.22
Post:	2.00 ±0.33	1.80 ±0.16 *
Delta:	0.06 ±0.38	-0.18 ±0.17 *
%Change:	3.41 ±18.93	-8.71 ±7.60 *

TABLE 12. Maximal respiratory quotients post exercise. Values are means ± standard deviation. *'s denote significance of difference between the three unconditioned exercisers and all 11 other subjects, P<0.05. For these data comparisons were also made between the three members of the exercise group who failed to condition themselves and the remaining eleven subjects.

FIGURE 9

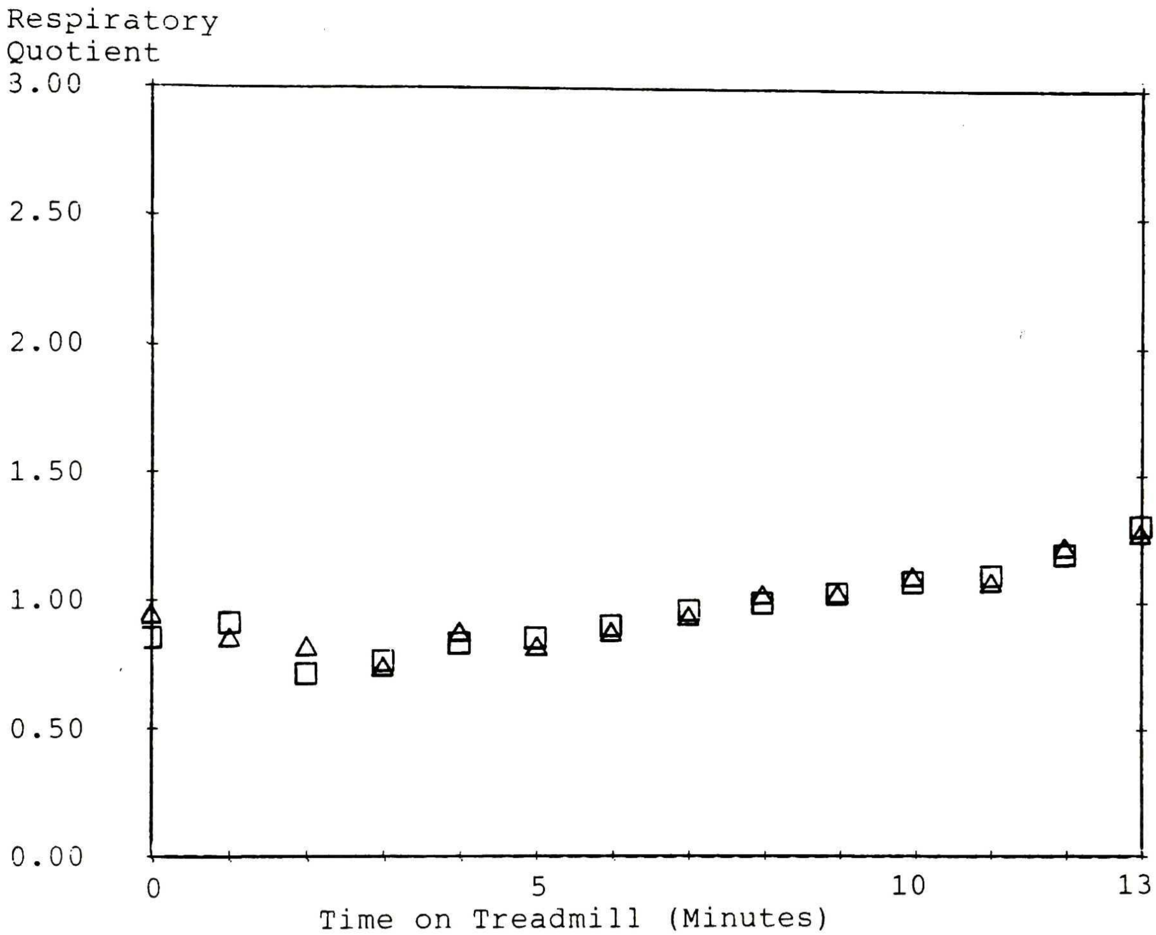


FIGURE 9. Plot of respiratory quotient versus time on treadmill for the three subjects in the exercise group who did not demonstrate increases in VO2max. Averages for the three subjects are plotted before (squares) and after (triangles) the conditioning period.

Mental Performance Data, Average Values

The mental performance data demonstrate a lack of relationship between increases in physical fitness and average performance on the mental performance tests. Tables 13 through 16 show the summary values for all four subtests (ADD2, LOGI, PAULI, and MAT2), looking at both percent correct, reaction times, and speed x accuracy products. (For the average data each set of 10 trials pre and post was averaged to a single number pre and post for each subject). While this study is most concerned with speed x accuracy product, it has been demonstrated that under some conditions reciprocal changes in accuracy and reaction time may occur which would not be reflected in the speed x accuracy product (Buck, 1980). Therefore reaction times and percent correct have been included here as well as speed x accuracy product.

As all statistics were performed on the control against either the conditioned or the exercise groups, the effects of practice are cancelled out. The only significant effects of the conditioning period are for the LOGI task, both in the change in percent correct (both delta and percent increase) control vs. exercise, and in the percent decrease of the reaction time for the conditioned group vs the control (Table 13). However, these changes were not reflected in the overall speed x accuracy product. If anything, the tendency was for the control group to improve more than the exercise or conditioned groups, although this was not statistically significant.

TABLE 13

ADD2, Longitudinal Study

		Control	Exercise	Conditioned
	n	7	7	4
Percent Correct,	Pre:	85.66 ±13.08	92.55 ±2.40	92.76 ±3.19
	Post:	85.03 ±14.62	90.88 ±5.38	87.42 ±4.11
	Delta:	-0.63 ±5.61	-1.67 ±5.96	-5.33 ±5.06
	%Change:	-0.79 ±6.65	-1.74 ±6.40	-5.67 ±5.42
Average Reaction Time,	Pre:	15.66 ±4.76	14.68 ±4.32	16.30 ±3.07
	Post:	14.12 ±4.40	13.44 ±3.82	15.06 ±2.87
	Delta:	-1.54 ±1.42	-1.24 ±0.66	-1.24 ±0.30
	%Change:	-9.61 ±8.86	-8.09 ±2.74	-7.64 ±1.27
Speed x Accuracy Product,	Pre:	6.15 ±2.31	6.94 ±2.32	5.93 ±1.27
	Post:	6.75 ±2.65	7.46 ±2.64	6.11 ±1.56
	Delta:	0.60 ±1.09	0.51 ±0.54	0.17 ±0.37
	%Change:	10.12 ±17.15	6.74 ±7.74	2.22 ±5.55

TABLE 13. Summary data for the two-digit addition task. Values are means ± standard deviations. "Pre" is the average for each subject before the conditioning period, "Post" is after the conditioning period, "Delta" is the difference between the two, and "%Change" is the percent increase. *'s denote significance of difference between the control and either the exercise or the conditioned group, P<0.05.

TABLE 14

LOGI, Longitudinal Study

		Control	Exercise	Conditioned
	n	7	7	4
Percent Correct,	Pre:	96.85 ±3.14	96.12 ±3.33	95.94 ±3.77
	Post:	95.33 ±2.63	97.44 ±1.85	96.95 ±2.15
	Delta:	-1.52 ±2.30	1.32 * ±1.82	1.01 ±1.74
	%Change:	-1.53 ±2.42	1.42 * ±1.93	1.10 ±1.88
Average Reaction Time,	Pre:	3.43 ±1.37	3.67 ±1.00	3.36 ±0.61
	Post:	2.74 ±0.98	3.14 ±0.72	3.02 ±0.52
	Delta:	-0.69 ±0.45	-0.53 ±0.32	-0.35 ±0.10
	%Change:	-19.00 ±6.54	-13.78 ±4.89	-10.18 * ±1.47
Speed x Accuracy Product,	Pre:	15.65 ±5.41	13.49 ±3.57	14.11 ±2.63
	Post:	18.56 ±6.21	16.03 ±4.17	16.08 ±3.03
	Delta:	2.91 ±1.84	2.54 ±1.14	1.97 ±0.70
	%Change:	19.76 ±10.00	19.42 ±8.53	14.00 ±4.62

TABLE 14. Summary data on the logical decision making task. Values are means ± standard deviations. "Pre" is the average of the average for each subject before the conditioning period, "Post" is after the conditioning period, "Delta" is the difference between the two, and "%Change" is the percent increase. *'s denote significance of difference between the control and either the exercise or the conditioned group, P<0.05.

TABLE 15

PAULI, Longitudinal Study

		Control	Exercise	Conditioned
	n	7	7	4
Percent Correct,	Pre:	97.47 ±2.69	94.80 ±8.81	92.00 ±11.43
	Post:	97.28 ±94.77	94.78 ±8.75	91.93 ±11.29
	Delta:	-0.19 ±1.87	-0.03 ±1.25	-0.06 ±1.50
	%Change:	-0.17 ±1.92	-0.02 ±1.29	-0.05 ±1.55
Average Reaction Time,	Pre:	1.07 ±0.25	0.98 ±0.22	0.98 ±0.18
	Post:	0.96 ±0.28	0.88 ±0.21	0.87 ±0.12
	Delta:	-0.12 ±0.10	-0.10 ±0.11	-0.11 ±0.15
	%Change:	-11.44 ±10.00	-10.23 ±9.78	-10.44 ±12.88
Speed x Accuracy Product,	Pre:	87.11 ±21.19	92.06 ±22.71	85.74 ±6.59
	Post:	98.91 ±29.53	102.21 ±27.61	95.59 ±6.05
	Delta:	11.80 ±14.16	10.15 ±10.00	9.85 ±11.79
	%Change:	12.78 ±13.83	10.99 ±11.23	12.28 ±14.56

TABLE 15. Summary data on the single digit addition task. Values are means ± standard deviations. "Pre" is the average of the average for each subject before the conditioning period, "Post" is after the conditioning period, "Delta" is the difference between the two, and "%Change" is the percent increase. *'s denote significance of difference between the control and either the exercise or the conditioned group, P<0.05.

TABLE 16

MAT2, Longitudinal Study

		Control	Exercise	Conditioned
	n	7	7	4
Percent Correct,	Pre:	70.21 ±4.98	73.21 ±4.18	71.62 ±4.92
	Post:	73.80 ±8.32	70.59 ±5.76	68.25 ±6.65
	Delta:	3.58 ±8.74	-2.63 ±5.52	-3.37 ±6.70
	%Change:	5.43 ±12.72	-3.47 ±7.58	-4.53 ±9.26
Average Reaction Time,	Pre:	1.94 ±0.53	1.74 ±0.65	1.49 ±0.29
	Post:	1.72 ±0.65	1.59 ±0.46	1.55 ±0.22
	Delta:	-0.23 ±0.27	-0.15 ±0.40	0.06 ±0.08
	%Change:	-13.09 ±15.32	-4.47 ±18.02	4.67 ±5.72
Speed x Accuracy Product,	Pre:	12.22 ±3.83	15.27 ±5.58	14.95 ±2.88
	Post:	15.63 ±7.06	13.88 ±4.35	12.09 ±3.25
	Delta:	3.41 ±5.57	-1.38 ±5.42	-2.86 ±5.89
	%Change:	32.25 ±53.87	-2.48 ±31.88	-14.82 ±31.00

TABLE 16. Summary data on the pattern recognition task. Values are means ± standard deviations. "Pre" is the average of the average for each subject before the conditioning period, "Post" is after the conditioning period, "Delta" is the difference between the two, and "%Change" is the percent increase. *'s denote significance of difference between the control and either the exercise or the conditioned group, P<0.05.

The effects of conditioning upon average values of mental performance can also be examined by trying to correlate objective changes in physical fitness (i.e. VO2max) with changes in mental performance. Even though as a group the controls had a negligible change in VO2max (-0.24 percent), there was significant individual variablity (standard deviation of ± 6.01 percent or absolute ± 2.46 $ml \cdot kg^{-1} \cdot min^{-1}$). There was also significant variability in changes in maximal oxygen consumption in the exercise group (standard deviation of ± 14.97 percent or absolute ± 6.41 $ml \cdot kg^{-1} \cdot min^{-1}$). Thus there is the possibility that correlating changes in conditioning with changes in mental performance without regard to group might show effects where a simple control vs exercise comparison would not. Graphs of delta speed x accuracy product vs delta VO2max for all four tests are shown in Figures 11 through 14. Graphs of percent increase in speed x accuracy product vs percent increase in VO2max are shown in Figures 15 through 18. There was negligible correlation between change in performance on any test and change in VO2max.

FIGURE 11

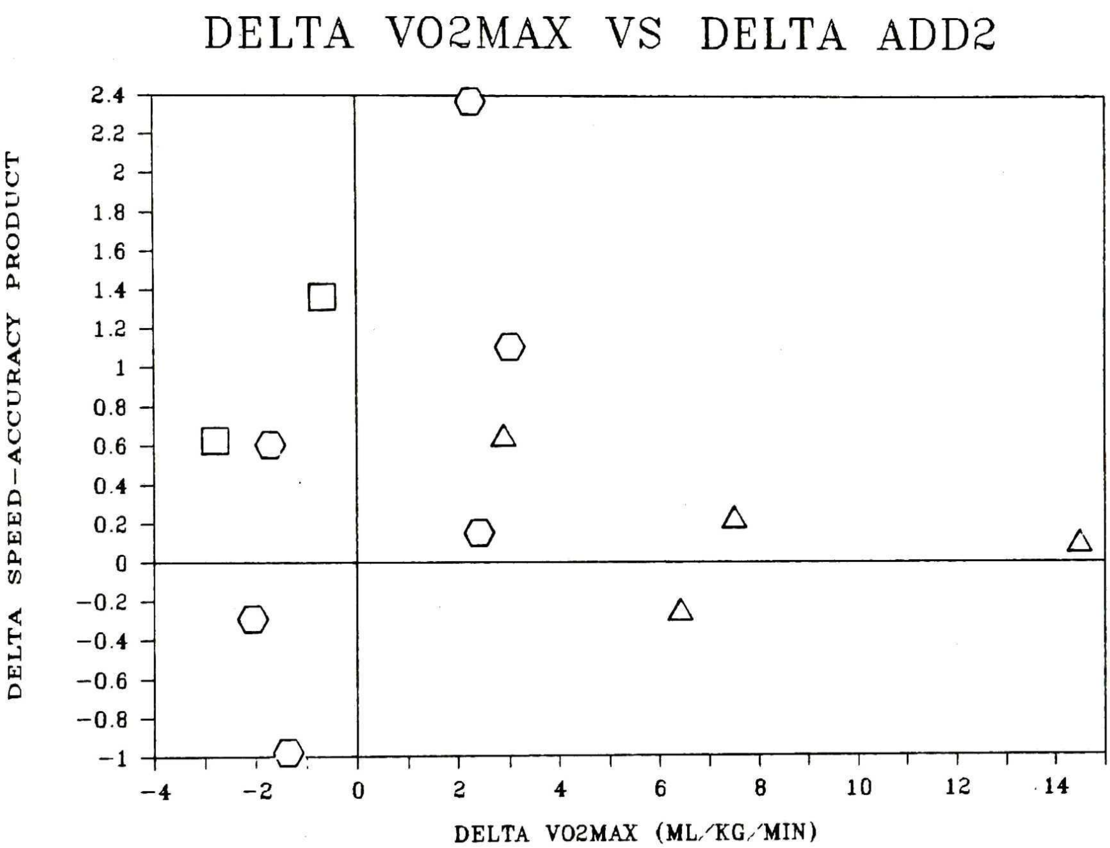


FIGURE 11. Delta VO2max versus delta ADD2 speed x accuracy product, all subjects. R=0.166, r2=0.028 (P>0.05). Hexagons represent control subjects, triangles represent subjects in the exercise group with increases in VO2max, and squares represent subjects in the exercise group with no increases in VO2max.

FIGURE 12

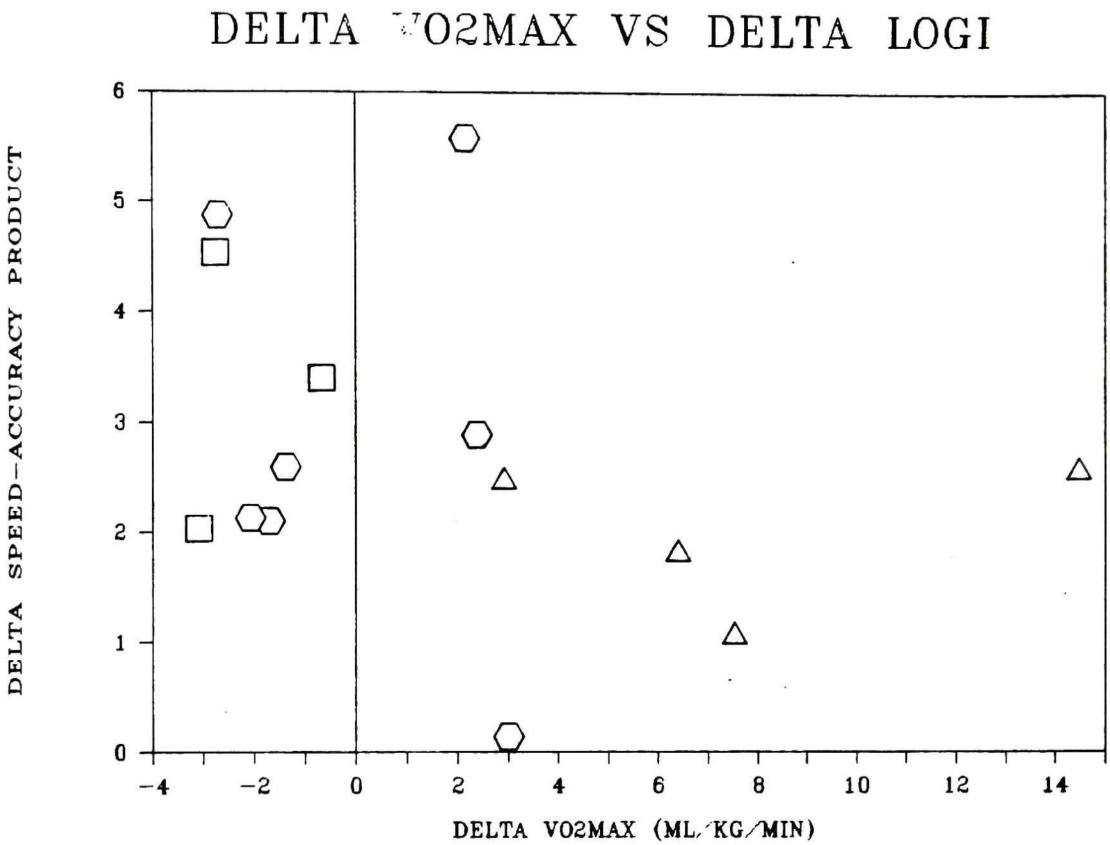


FIGURE 12. Delta VO2max versus delta LOGI speed x accuracy product, all subjects. R=0.306, r2=0.093 (P>0.05). Hexagons represent control subjects, triangles represent subjects in the exercise group with increases in VO2max, and squares represent subjects in the exercise group with no increases in VO2max.

FIGURE 13

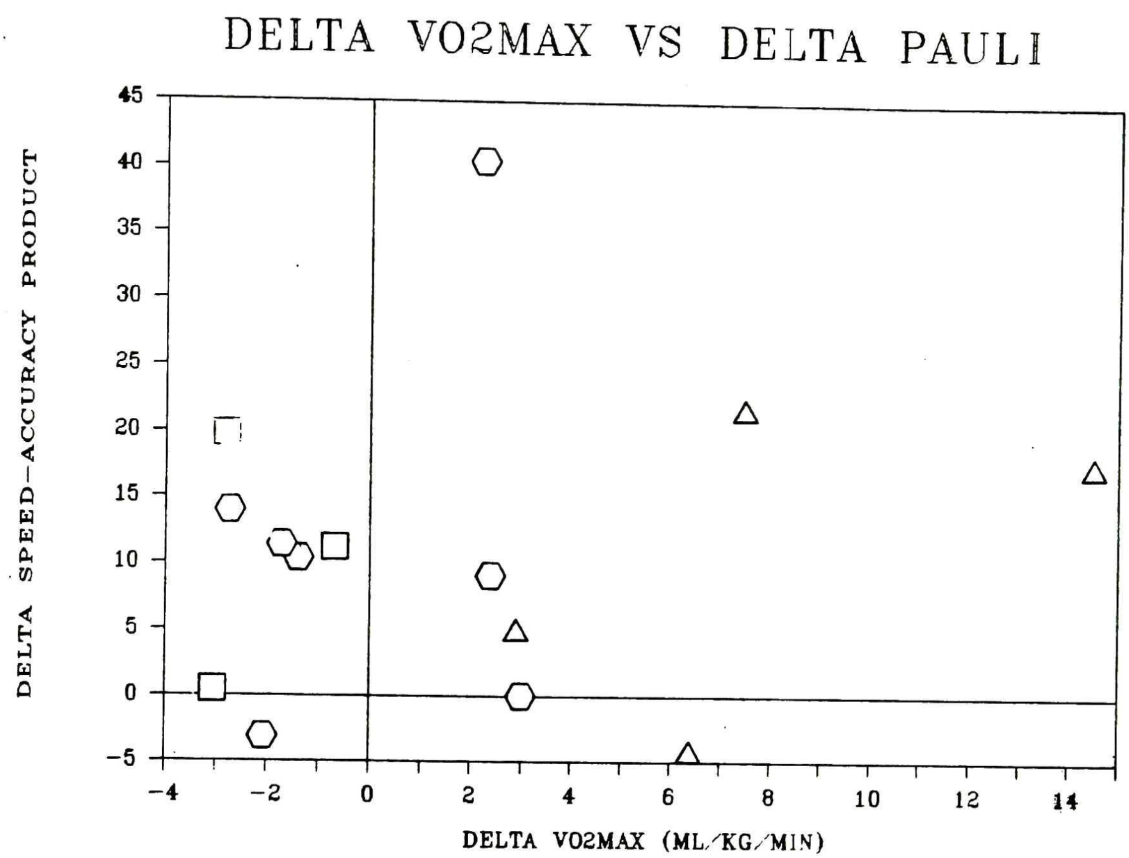


FIGURE 13. Delta VO2max versus delta PAULI speed x accuracy product, all subjects. R=0.145, r2=0.021 (P>0.05). Hexagons represent control subjects, triangles represent subjects in the exercise group with increases in VO2max, and squares represent subjects in the exercise group with no increases in VO2max.

FIGURE 14

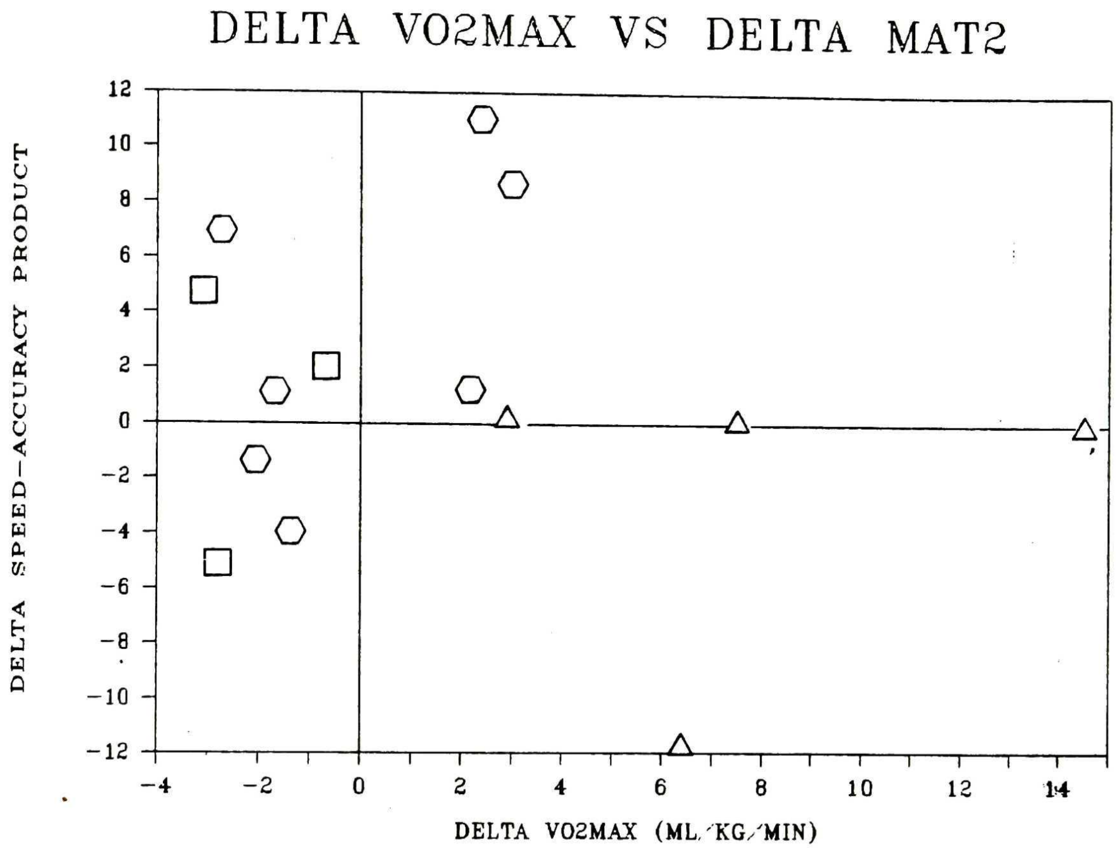


FIGURE 14. Delta VO2max versus delta MAT2 speed x accuracy product, all subjects. R=0.151, r2=0.023 (P>0.05). Hexagons represent control subjects, triangles represent subjects in the exercise group with increases in VO2max, and squares represent subjects in the exercise group with no increases in VO2max.

FIGURE 15

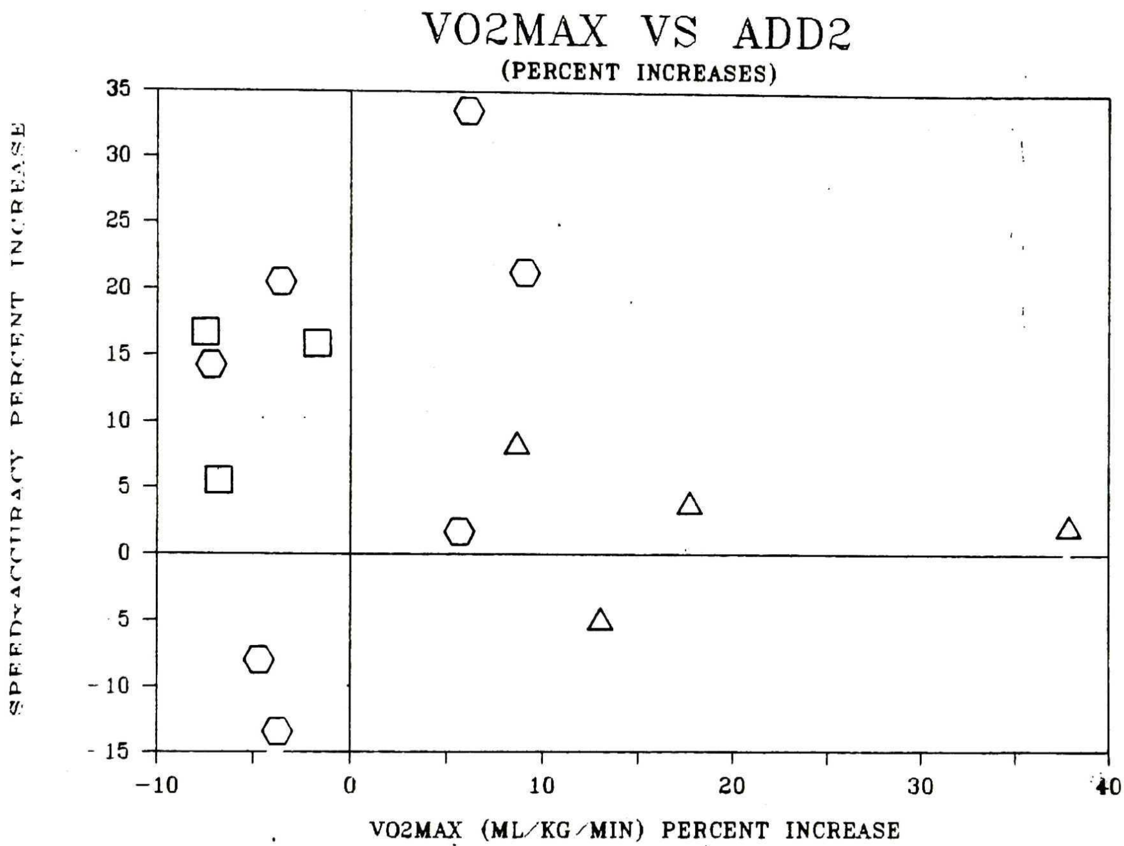


FIGURE 15. Percent increase in VO2max versus percent increase in ADD2 speed x accuracy product. R=0.120, r2=0.015 (P>0.05). Hexagons represent control subjects, triangles represent subjects in the exercise group with increases in VO2max, and squares represent subjects in the exercise group with no increases in VO2max.

FIGURE 16

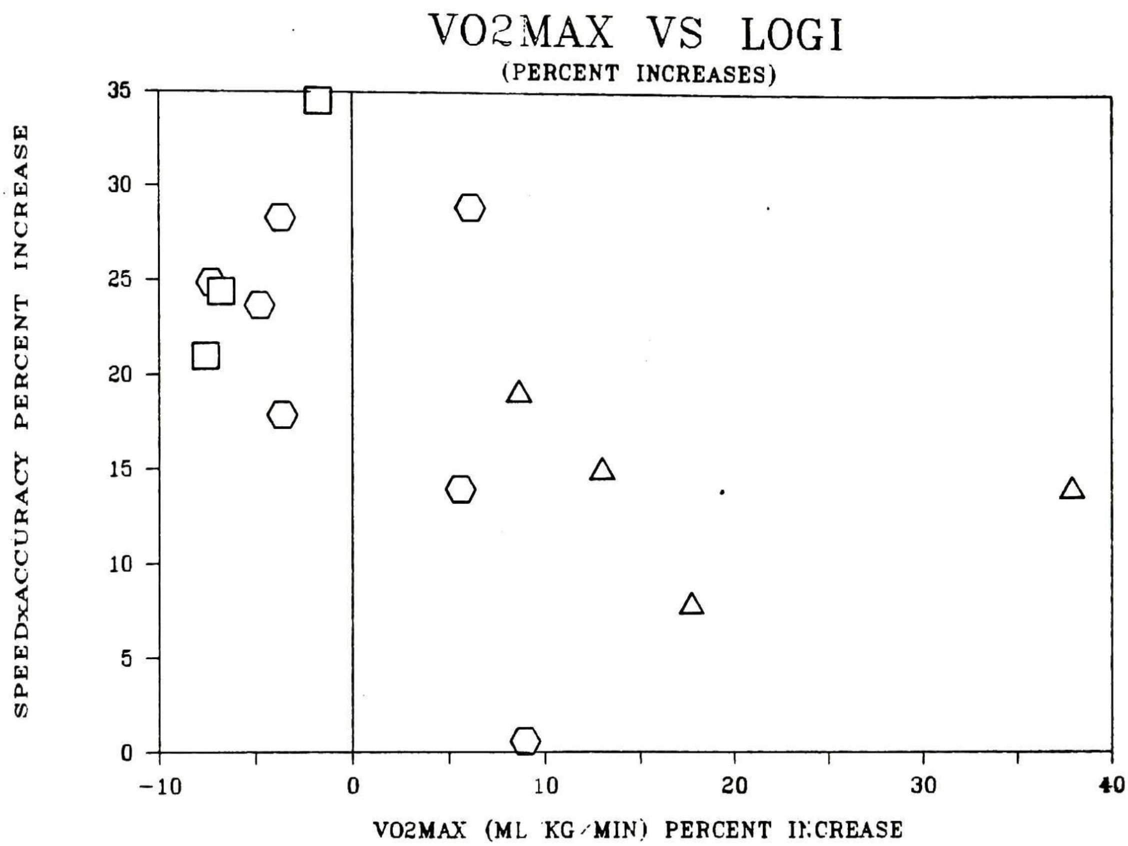


FIGURE 16. Percent increase in VO2max versus percent increase in LOGI speed x accuracy product. R=0.527, r2=0.278 (P>0.05). Hexagons represent control subjects, triangles represent subjects in the exercise group with increases in VO2max, and squares represent subjects in the exercise group with no increases in VO2max.

FIGURE 17

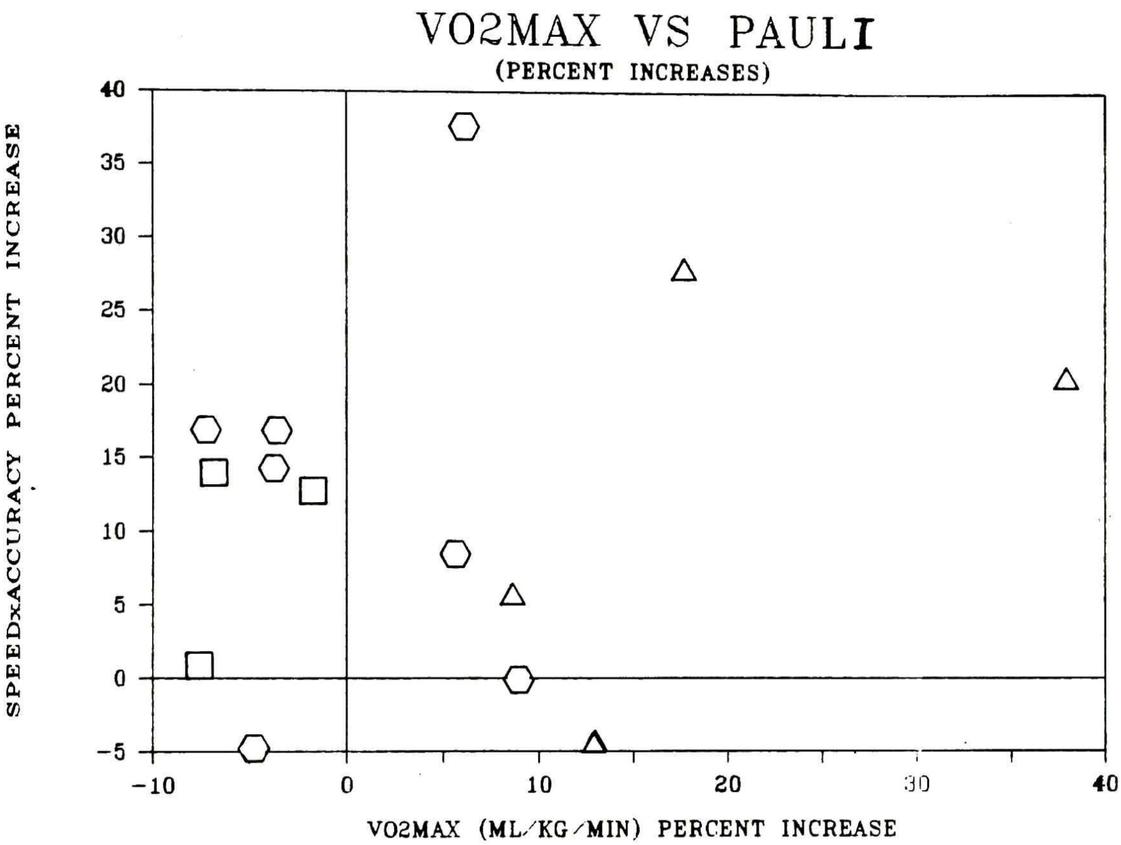


FIGURE 17. Percent increase in VO2max versus percent increase in PAULI speed x accuracy product. R=0.226, r2=0.051 (P>0.05). Hexagons represent control subjects, triangles represent subjects in the exercise group with increases in VO2max, and squares represent subjects in the exercise group with no increases in VO2max.

FIGURE 18

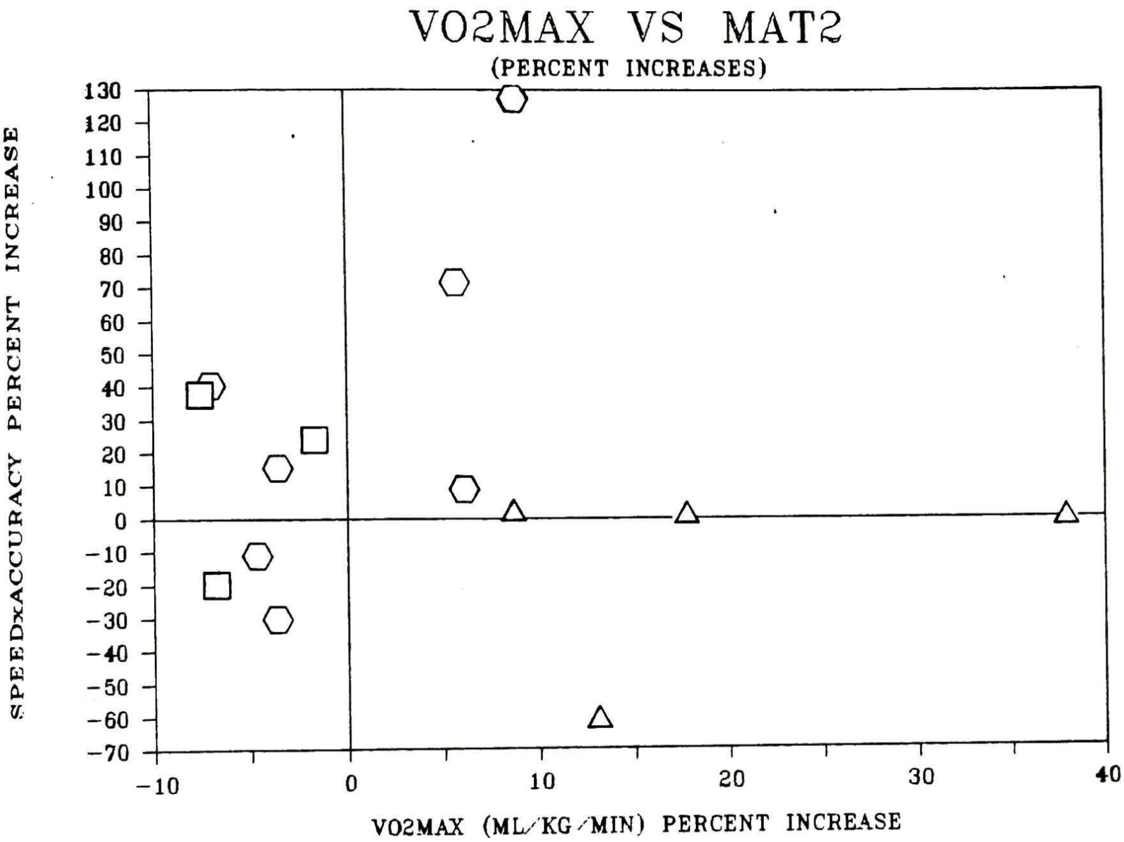


FIGURE 18. Percent increase in VO2max versus percent increase in MAT2 speed x accuracy product. R=0.062, r2=0.004 (P>0.05). Hexagons represent control subjects, triangles represent subjects in the exercise group with increases in VO2max, and squares represent subjects in the exercise group with no increases in VO2max.

Mental Performance Data, Training Effects

In general, the subjects showed increases in performance on many test components when the average of all tests at the beginning of the study was compared to the average of all tests at the end. However, as the increases were of equal magnitude for both the control and the experimental group(s) none of this can be attributed to the effects of physical conditioning. Figures 19 through 30 illustrate the effects of practice in more detail. In all these illustrations, each data point represents the average of all fourteen subjects (control + experimental), and the error bars are standard deviations. It is important to define the effects of practice on these tests so that when attempting to detect the effects of time of day upon mental performance the effects of practice can be subtracted out. It is also important to verify that for a given test changes in performance depend primarily on changes in either reaction time or percent correct but not both, so that further analysis can be done solely on the speed x accuracy product.

Graphs of ADD2 vs presentation order for percent correct, average reaction time and speed x accuracy product are shown in Figures 19, 20 and 21 respectively. Except for the first two practice sessions there were no significant practice effects for this task as determined by one-way ANOVA with repeated measures (Winer, 1971). Speed x accuracy product correlated much more strongly with reaction time (r=0.909) than with percent correct (r=0.572).

FIGURE 19

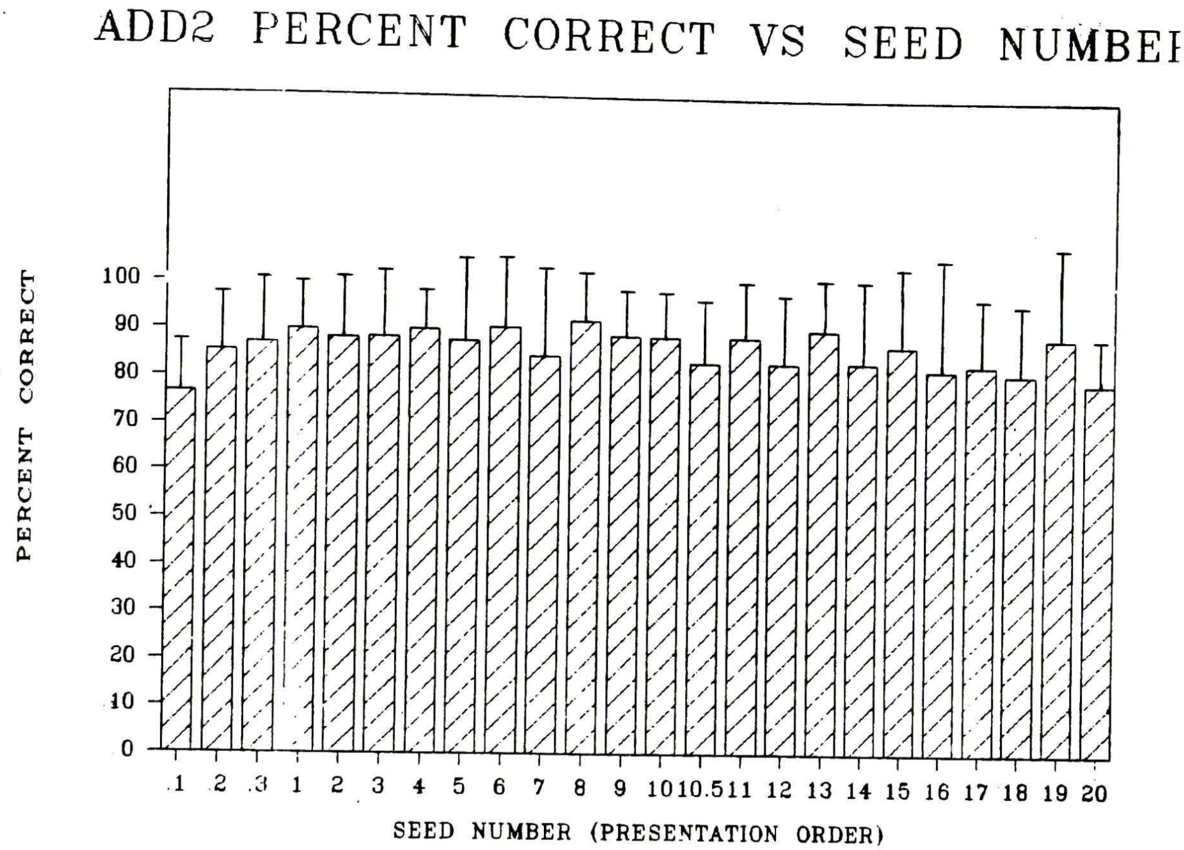


FIGURE 19. Graph of percent correct for ADD2 (two-digit addition) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed no significant effects of order of presentation on percent correct.

FIGURE 20

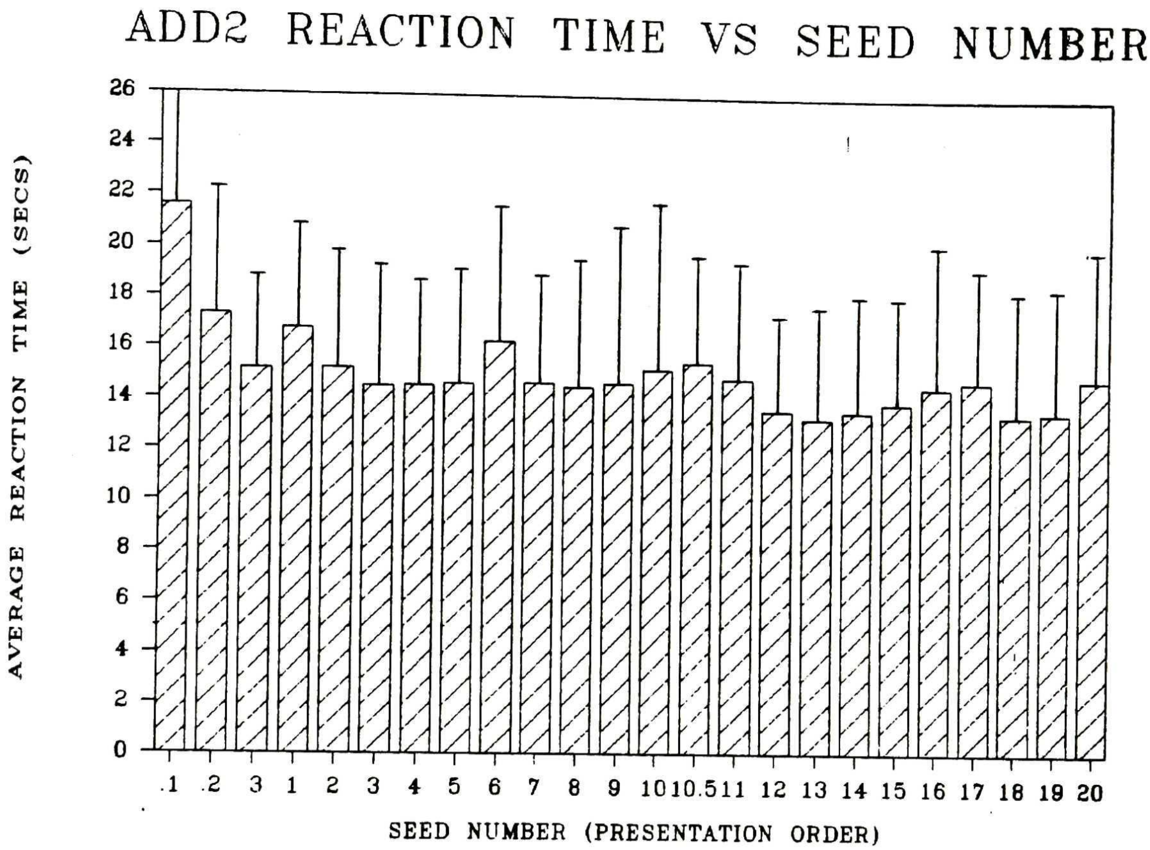


FIGURE 20. Graph of average reaction times for ADD2 (two-digit addition) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed no significant effects of order of presentation on average reaction times.

FIGURE 21

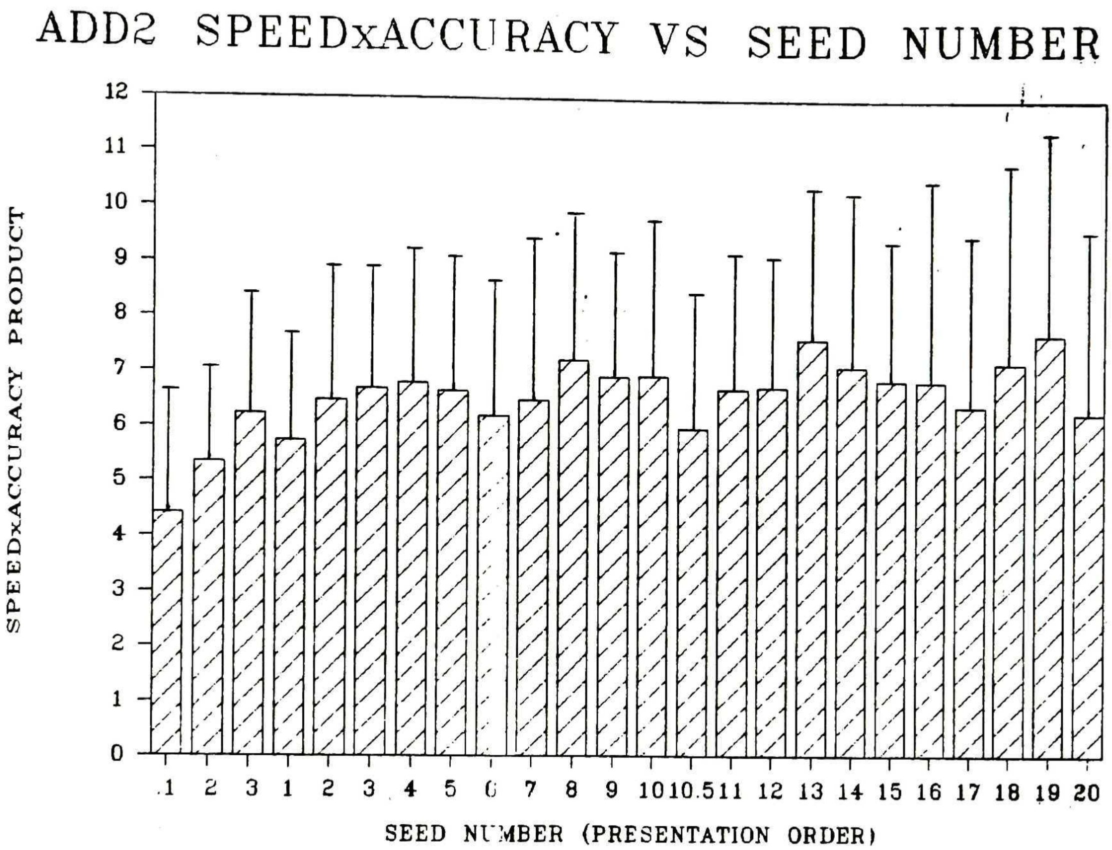


FIGURE 21. Graph of speed x accuracy product for ADD2 (two-digit addition) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed no significant effects of order of presentation on speed x accuracy products. Speed x accuracy product correlated much more strongly with reaction time (r=0.909) than with percent correct (r=0.572).

Graphs of LOGI vs presentation order are displayed in Figures 22, 23 and 24. There was a tendency for percent correct to increase with training, but if the practice sessions were omitted this did not become statistically significant. All the subjects rapidly acquired the ability to score 90% or better on this test. The effect of training on reaction time, however, was quite pronounced. The increase in LOGI speed x accuracy product vs practice is thus primarily a function of decreasing reaction times. Speed x accuracy product also correlates much more strongly with reaction time (r=0.886) than with percent correct (r=0.365).

FIGURE 22

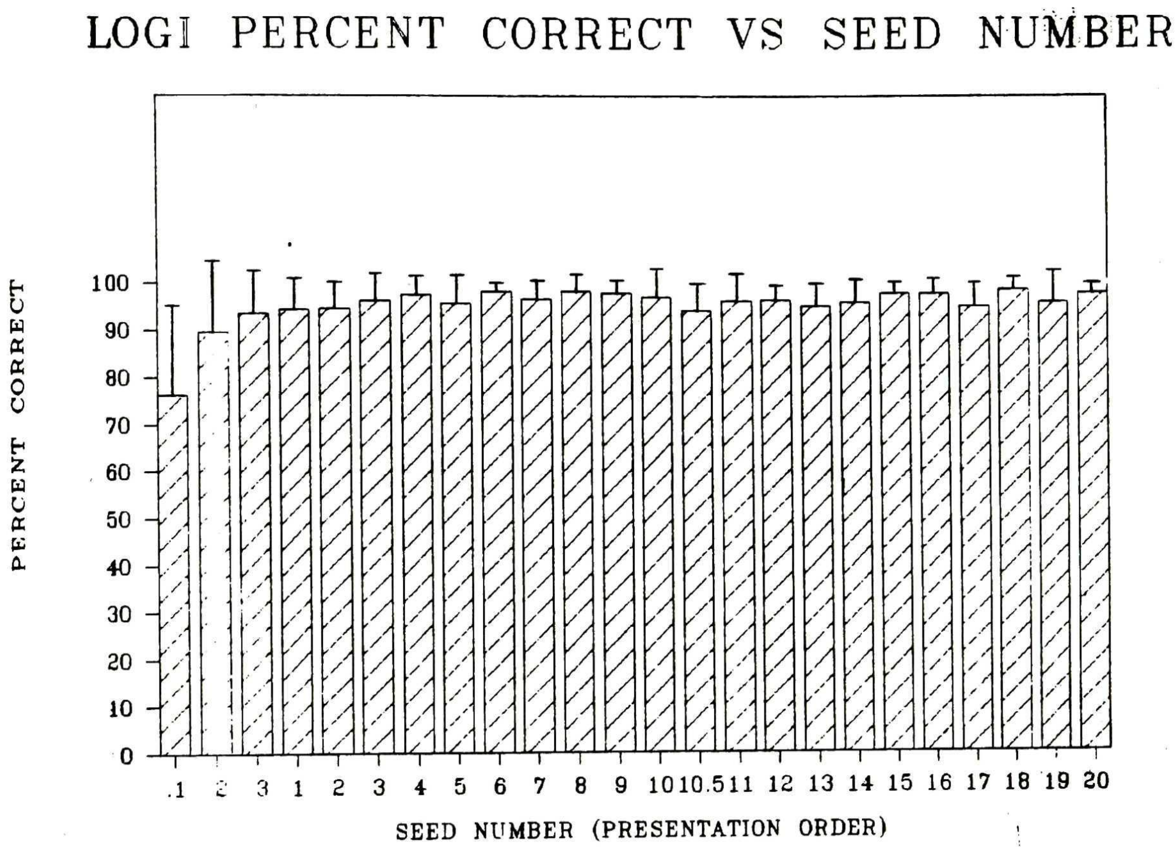


FIGURE 22. Graph of percent correct for LOGI (logical decision-making) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed significant effects of order of presentation on percent correct, $P<0.05$, but only if the practice sessions were included.

FIGURE 23

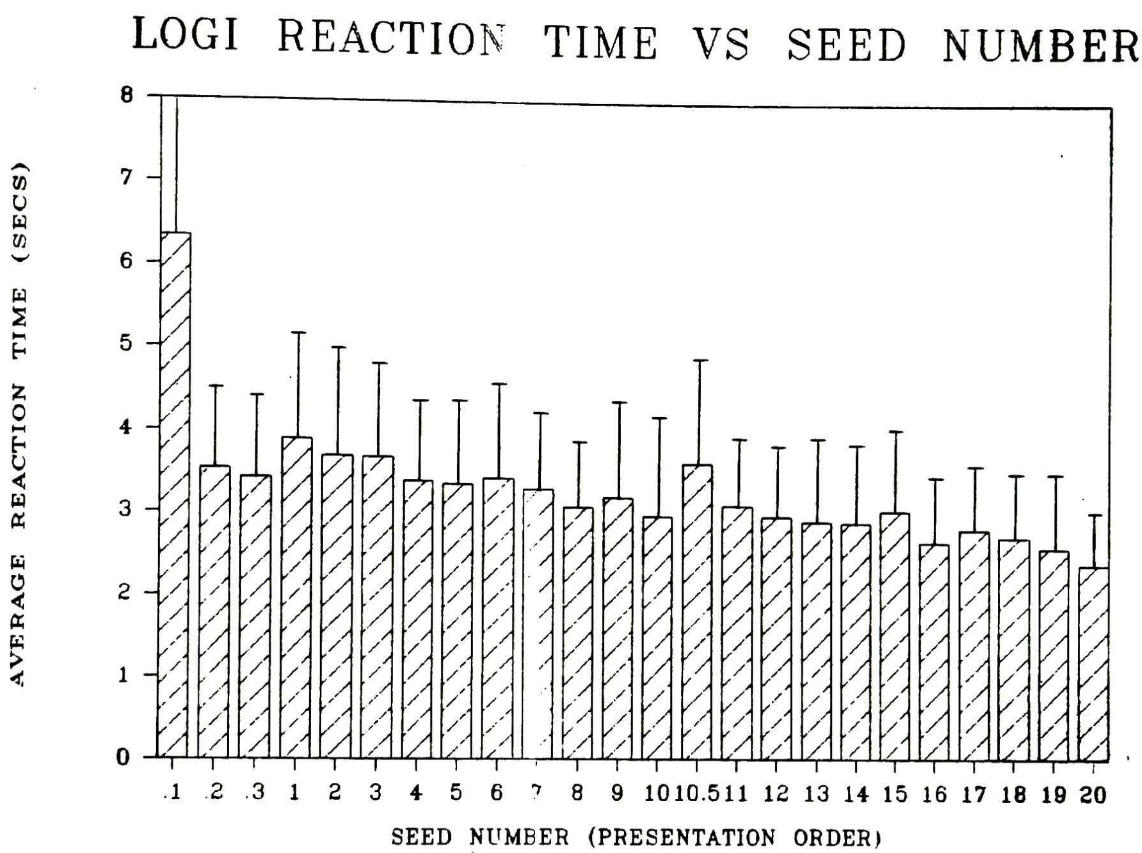


FIGURE 23. Graph of average reaction times for LOGI (logical decision-making) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed significant effects of order of presentation on average reaction times, $P<0.05$.

FIGURE 24

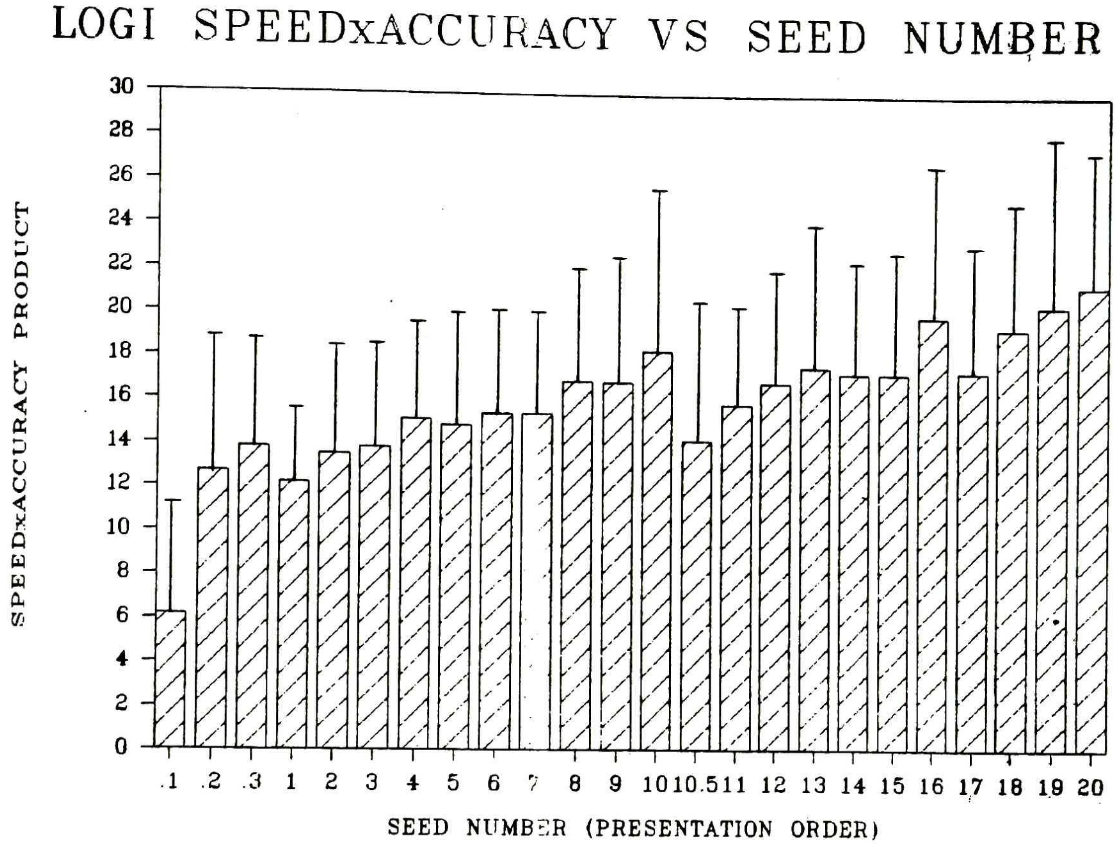


FIGURE 24. Graph of speed x accuracy product for LOGI (logical decision-making) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed significant effects of order of presentation on speed x accuracy products, $P<0.05$. Speed x accuracy product correlated more with reaction time ($r=0.886$) than with percent correct ($r=0.365$).

Graphs of PAULI vs presentation order are shown in Figures 25, 26 and 27. As with LOGI, percent correct is quite stable, and correlates poorly with speed x accuracy product (r=0.285). Reaction times steadily decreased with practice and correlated strongly with speed x accuracy product (r=0.921). Thus changes in speed x accuracy product for PAULI are primarily a function of changes in reaction time.

FIGURE 25

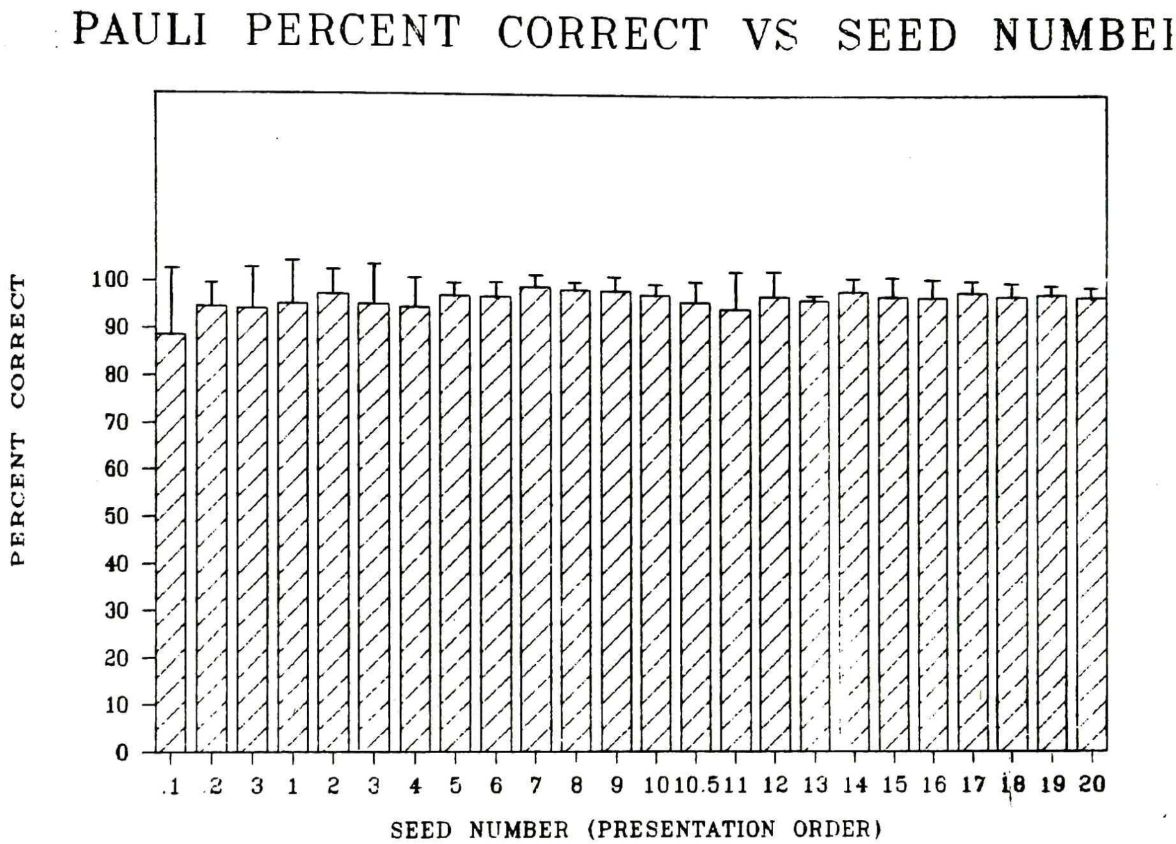


FIGURE 25. Graph of percent correct for PAULI (single digit addition) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed no significant effects of order of presentation on percent correct.

FIGURE 26

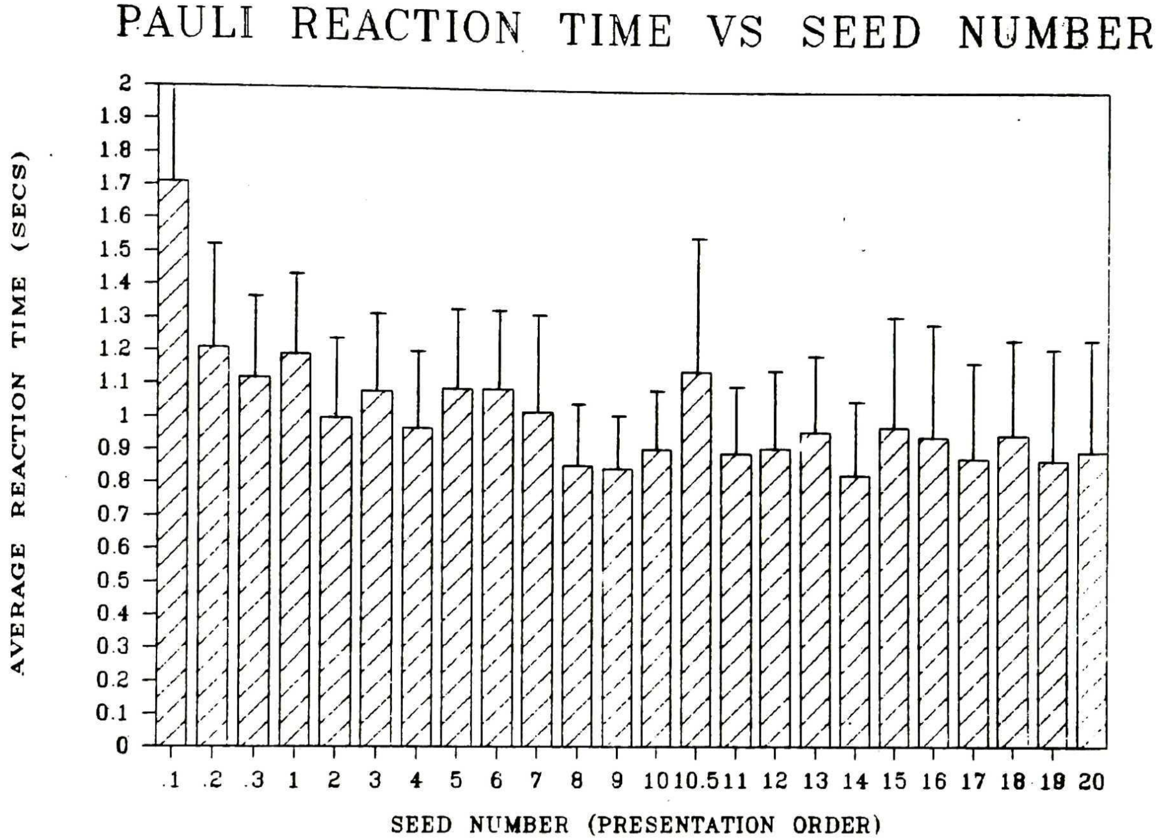


FIGURE 26. Graph of average reaction times for PAULI (single digit addition) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed significant effects of order of presentation on average reaction times, $P<0.05$.

FIGURE 27

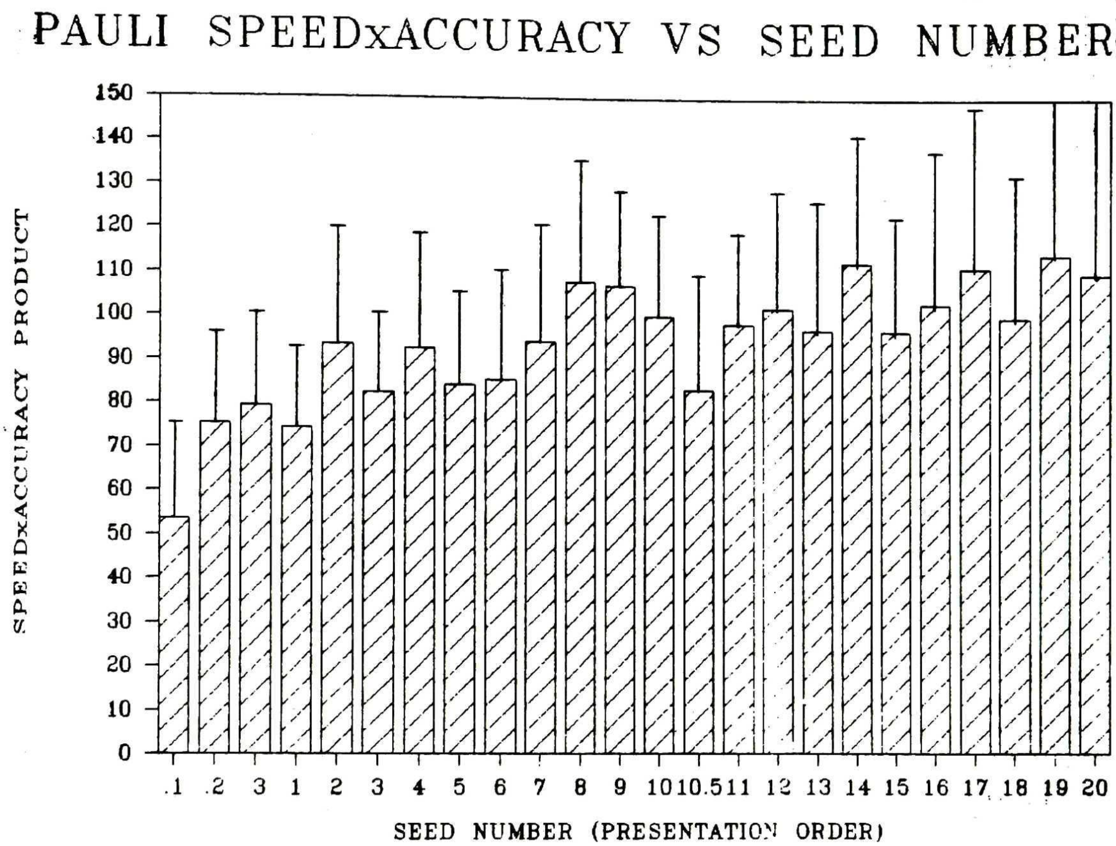


FIGURE 27. Graph of speed x accuracy product for PAULI (single digit addition) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed significant effects of order of presentation on speed x accuracy product, $P<0.05$. Speed x accuracy product correlated much more with reaction time ($r=0.921$) than with percent correct ($r=0.285$).

Graphs of MAT2 vs. presentation order are in Figures 28 through 30. Performance on this task as a function of practice was relatively unstable. Reaction times did not show a significant dependence on order of presentation, but both percent correct and speed x accuracy product showed significant effects. Speed x accuracy product correlated more with percent correct (r=0.837) than with reaction time (r=0.476). However, rather than steadily increasing or decreasing as was the case for both LOGI and PAULI, there was an almost random dependence of performance upon the specific trial number. Given that there were only ten patterns to be matched for each trial and that missing one pattern would cause a ten percent change in percent correct, it is possible that some patterns proved intrinsically more difficult to match than others for many of the subjects in this study.

FIGURE 28

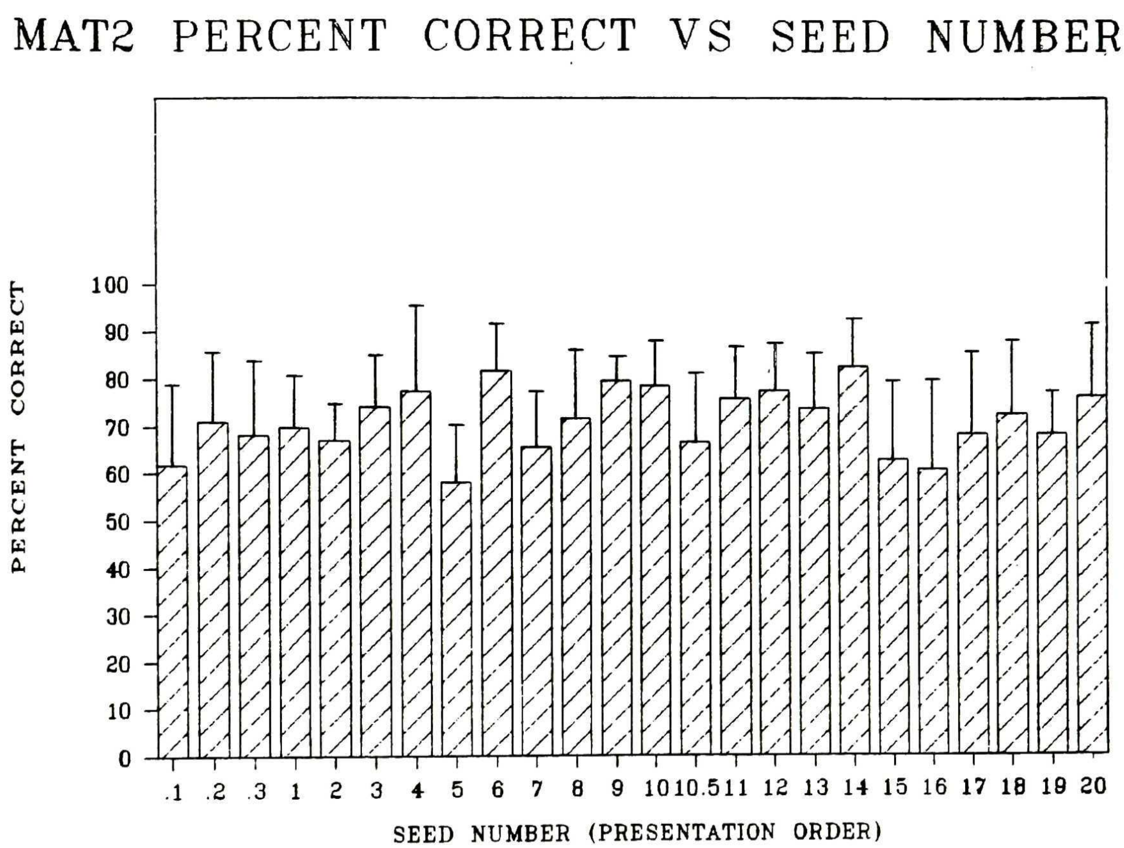


FIGURE 28. Graph of percent correct for MAT2 (spatial pattern recognition) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed significant effects of order of presentation on percent correct, P<0.05.

FIGURE 29

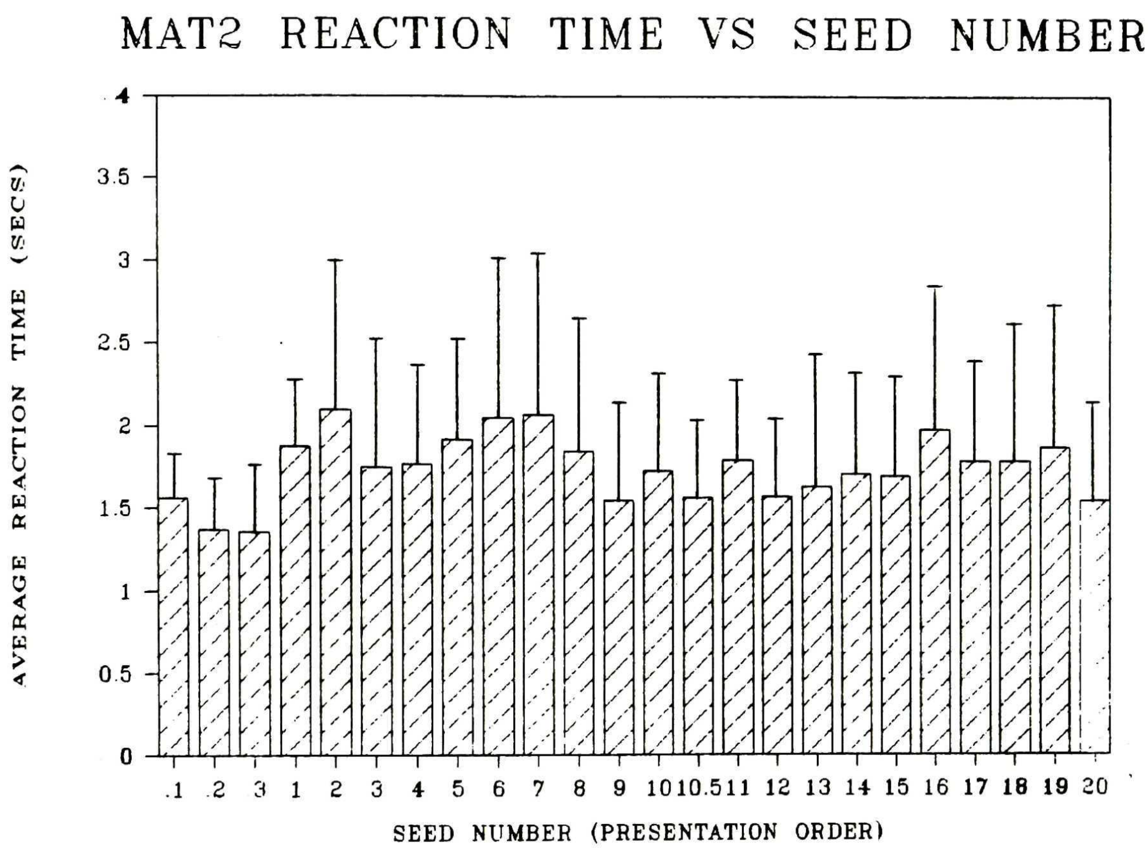


FIGURE 29. Graph of average reaction times for MAT2 (spatial pattern recognition) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed no significant effects of order of presentation on average reaction times. Speed x accuracy product correlated more with percent correct (r=0.837) than with reaction time (r=0.476).

FIGURE 30

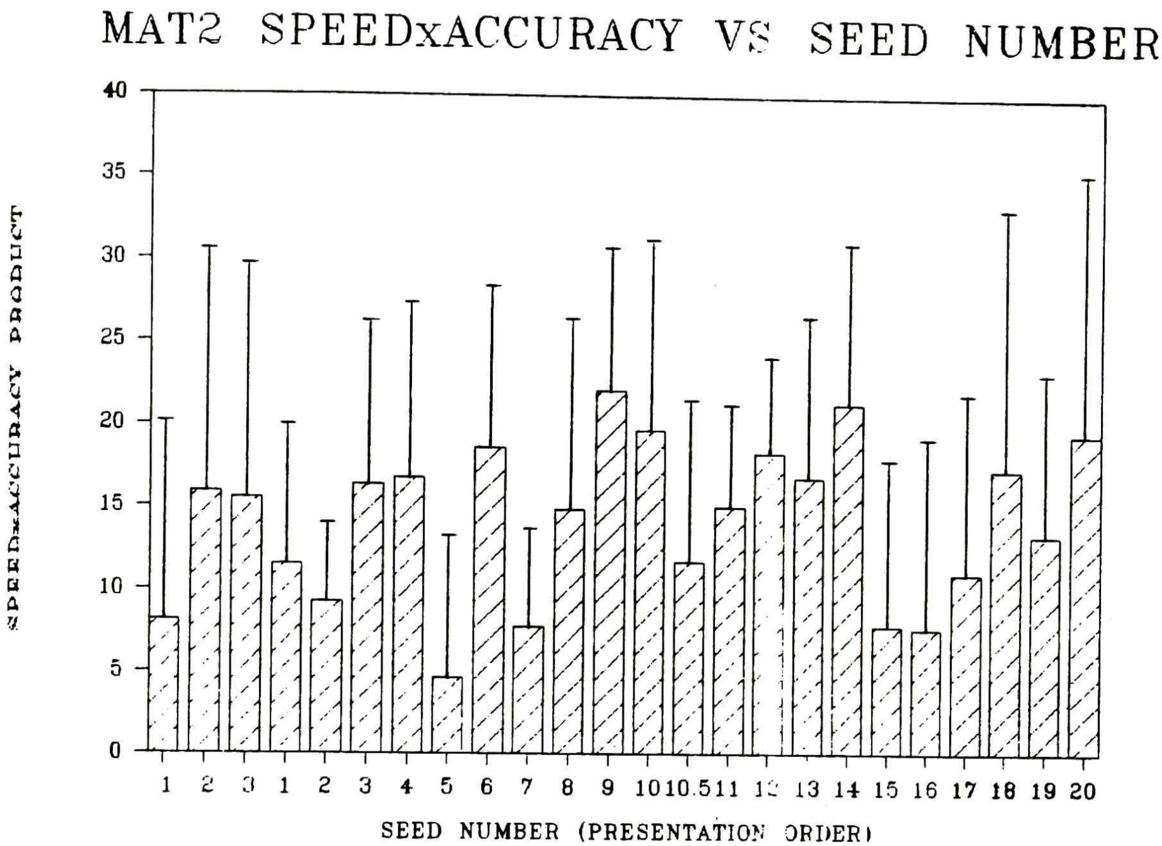


FIGURE 30. Graph of speed x accuracy product for MAT2 (spatial pattern recognition) vs seed number. Seeds 0.1, 0.2 and 0.3 are practice sessions, seeds 1-10 are the first ten trials, seed 10.5 is the first practice session after the exercise or control period, and seeds 11-20 are the final ten trials. Error bars are standard deviations. One-way ANOVA with repeated measures on this data showed significant effects of order of presentation on speed x accuracy product.

Mental Performance Data, Circadian Rhythms

No effect of time of day on mental performance was detected for any test under any condition. Therefore the effect of conditioning upon the circadian variability of mental performance could not be well defined. Graphs 31 through 34 show the effects of time of day vs speed x accuracy product for all four tasks. These graphs were done by averaging all non-practice session tests for all subjects, and both pre- and post-. Looking at the speed x accuracy products for each group separately, either before or after the conditioning period, also yielded negative results. These data were combined after analysis demonstrated no effect of the exercise program upon circadian rhythms. Looked at in this way there were no significant circadian rhythms for any of the four tasks as determined by one-way ANOVA with repeated measures (Winer, 1971). Finally, correcting for the effect of practice through linear regression analysis of speed x accuracy product revealed no circadian rhythms to mental performance.

FIGURE 31

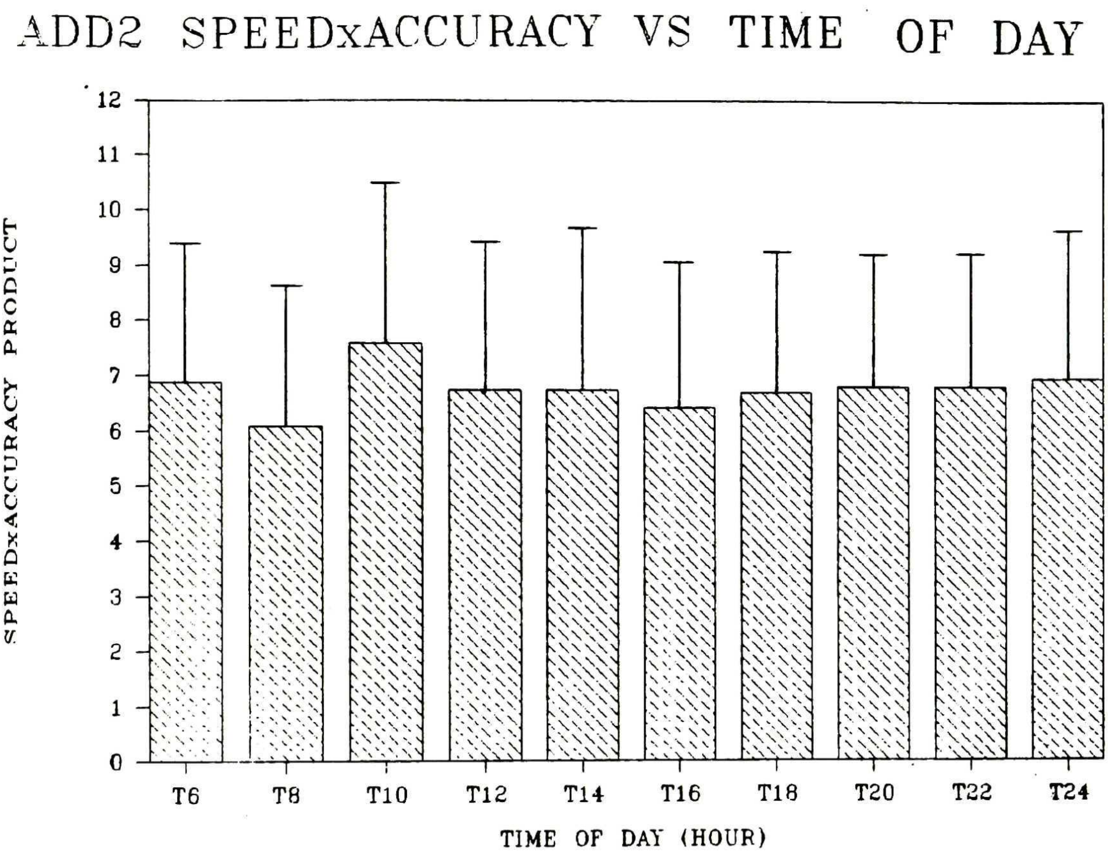


FIGURE 31. Graph of ADD2 (two-digit addition) speed x accuracy product vs time of day. Each bar is the average for all subjects pre and post. One-way ANOVA with repeated measures shows no significant effects of time of day. Error bars are standard deviations.

FIGURE 32

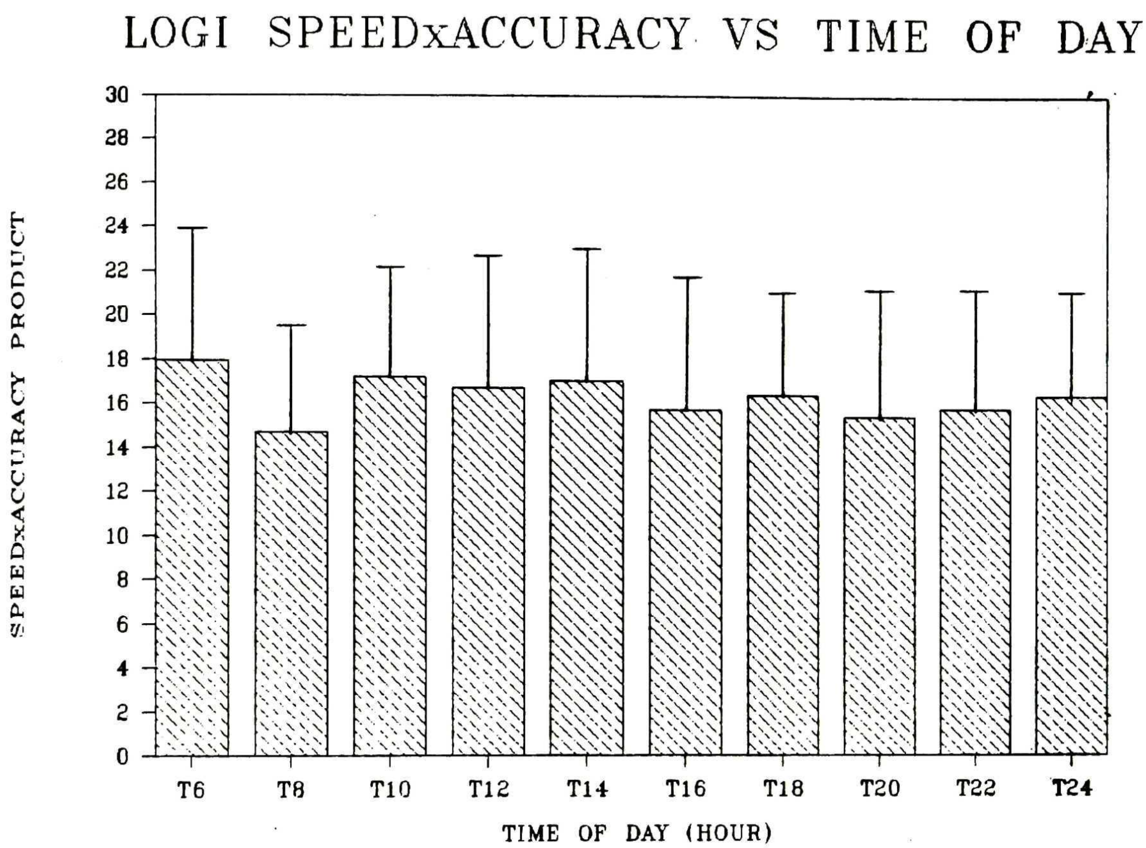


FIGURE 32. Graph of LOGI (logical decision making) speed x accuracy product vs time of day. Each bar is the average for all subjects pre and post. One-way ANOVA with repeated measures shows no significant effects of time of day. Error bars are standard deviations.

FIGURE 33

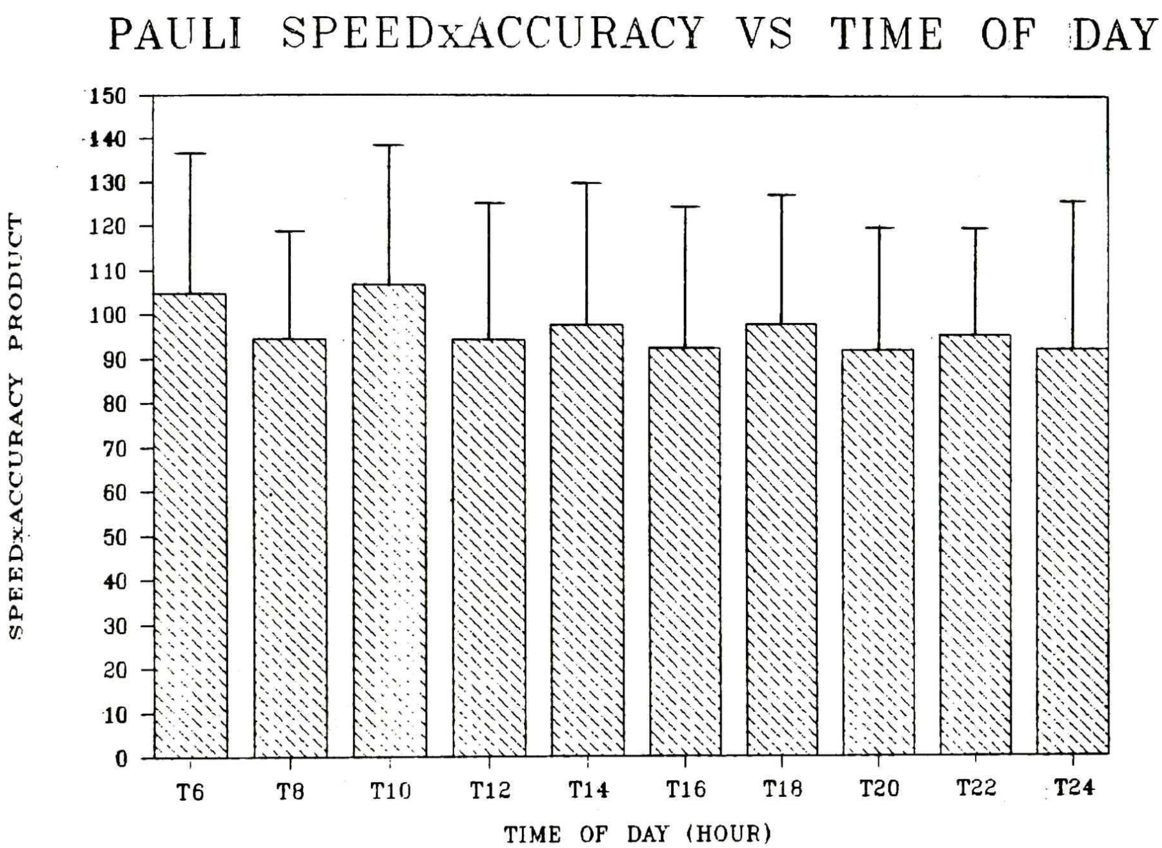


FIGURE 33. Graph of PAULI (single-digit addition) speed x accuracy product vs time of day. Each bar is the average for all subjects pre and post. One-way ANOVA with repeated measures shows no significant effects of time of day. Error bars are standard deviations.

FIGURE 34

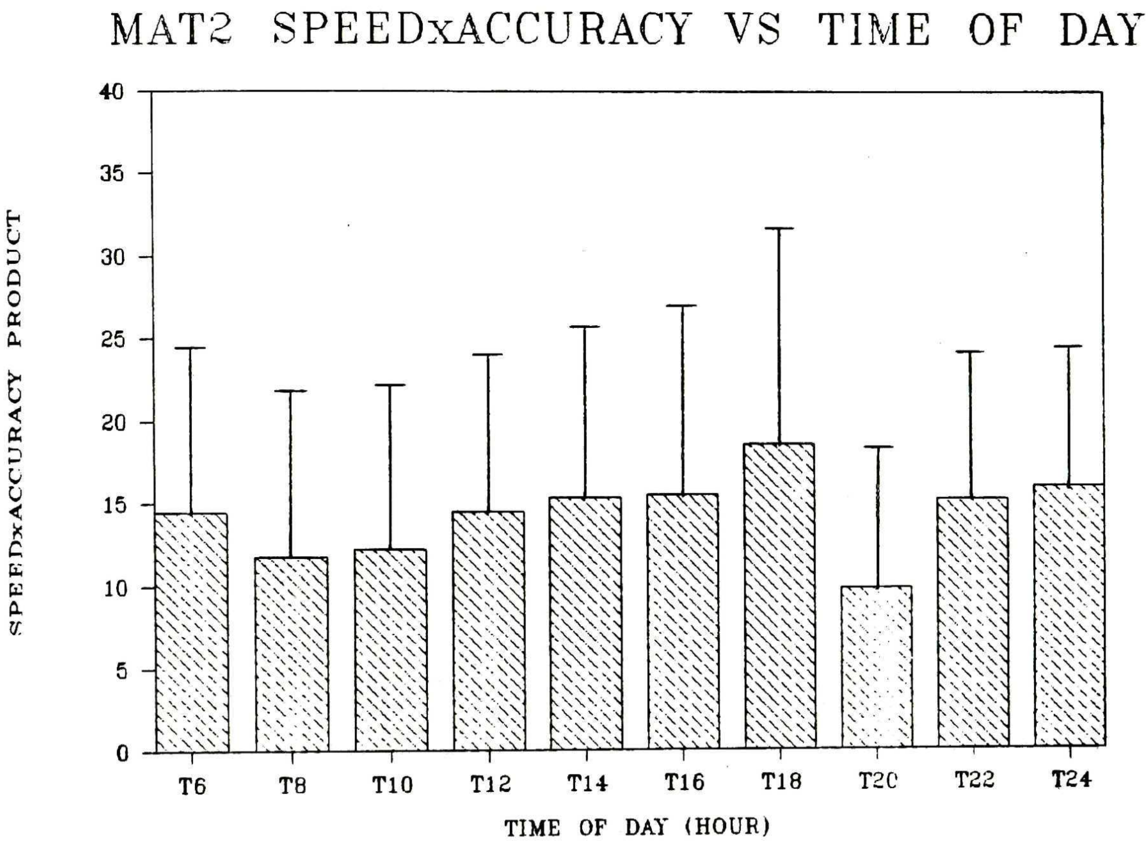


FIGURE 34. Graph of MAT2 (spatial pattern recognition) speed x accuracy product vs time of day. Each bar is the average for all subjects pre and post. One-way ANOVA with repeated measures shows no significant effects of time of day. Error bars are standard deviations.

Beta Error

This study is to some degree hampered by the small number of subjects who successfully raised their aerobic capacities. However, the dramatic lack of effect of conditioning upon the mental performance tests used in the study offsets the small sample size. This is borne out by two separate statistical arguements. First, by hypothetically increasing the number of subjects in the control and conditioned groups while keeping the group means and variances constant, it was found that even an infinite number of subjects would not yield a statistically significant difference at an alpha level ("p-value") of 0.05.

Another statistical approach is to analyze the beta-error. Alpha-error is the probability that the null hypothesis - in this case the hypothesis that aerobic conditioning has no effect upon scores on this panel of mental performance tests - is true when we have rejected it. Beta-error is the flip side of this arguement: the probability that the null hypothesis is false when we have accepted it (Dotson and Kirkendall, 1974). In other words, how likely is it that an enhancement of aerobic capacity may improve performance on the PAB but was not evident in the study because of sample size, the stringency of our statistical tests, or other factors. The size of the beta-error depends upon four items: the alpha level set for rejection of the null hypothesis ("p value"), the

variability of the tests used to measure mental performance when given repeatedly to the same subject, the number of subjects and the magnitude of the differences being sought between groups. These elements can be summarized by measuring the "power" of a test, defined as 1.0 - beta-error. The lower the chance of accepting a false hypothesis of no effect, the greater the power. Values of power of 0.75 or greater are considered acceptable.

For the PAB tests used in this study, an analysis of beta-error was performed. Data on test variability was obtained from the test developers in the Neuropsychiatry Division of the Walter Reed Army Institute of Research. The standard deviations (in percent) of within subject testing was 8.9% for ADD2, 8.2% for LOGI, 7.5% for PAULI and 68% for MAT2. Power values were derived from standard tables (Dotson and Kirkendall, 1974). Graphs of power against the percent change between the control (n=7) conditioned (n=4) groups are shown in Figures 35 through 38. There is no simple method for computing power for unequal sample sizes; the curves for n=7,7 and n=4,4 are shown with the assumption that the power values for n=4,7 lies between the two extremes. Using a power of 0.75 as our acceptable threshold, these data show that any effect of aerobic conditioning upon mental performance measured ADD2, LOGI or PAULI was, at best, quite small, i.e., less than 10% improvement in performance. Because of the extreme variability of the spatial task, MAT2, an analysis of the

beta-error only rules out differences between the control and conditioned groups of greater than 100%. I am confident in concluding that the small sample size did not prevent our observing large differences between the two groups and certainly not of the magnitude found in the pilot study.

FIGURE 35

Power vs size of detectable difference for ADD2

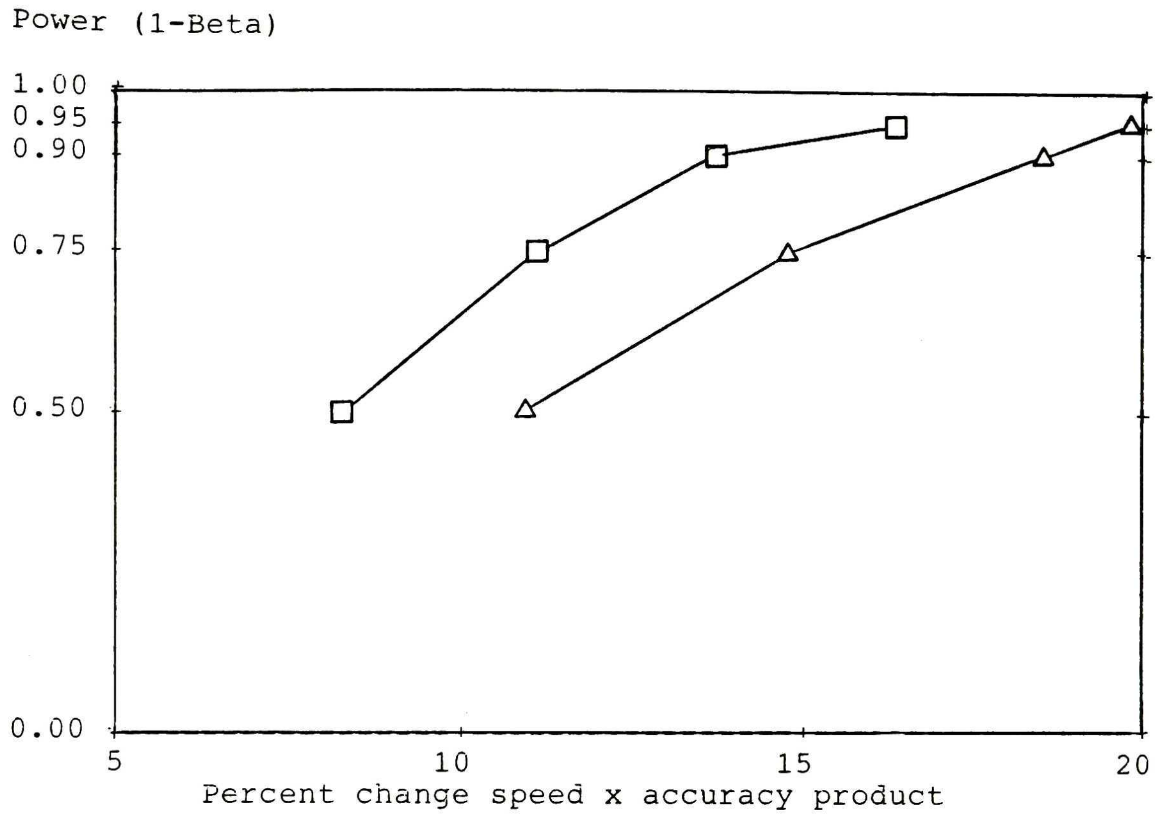


FIGURE 35. Graph of power (1 - Beta error) versus percent change in speed x accuracy product for ADD2. Squares are for 7,7 subjects and triangles are for 4,4 subjects.

FIGURE 36

Power vs size of detectable difference for LOGI

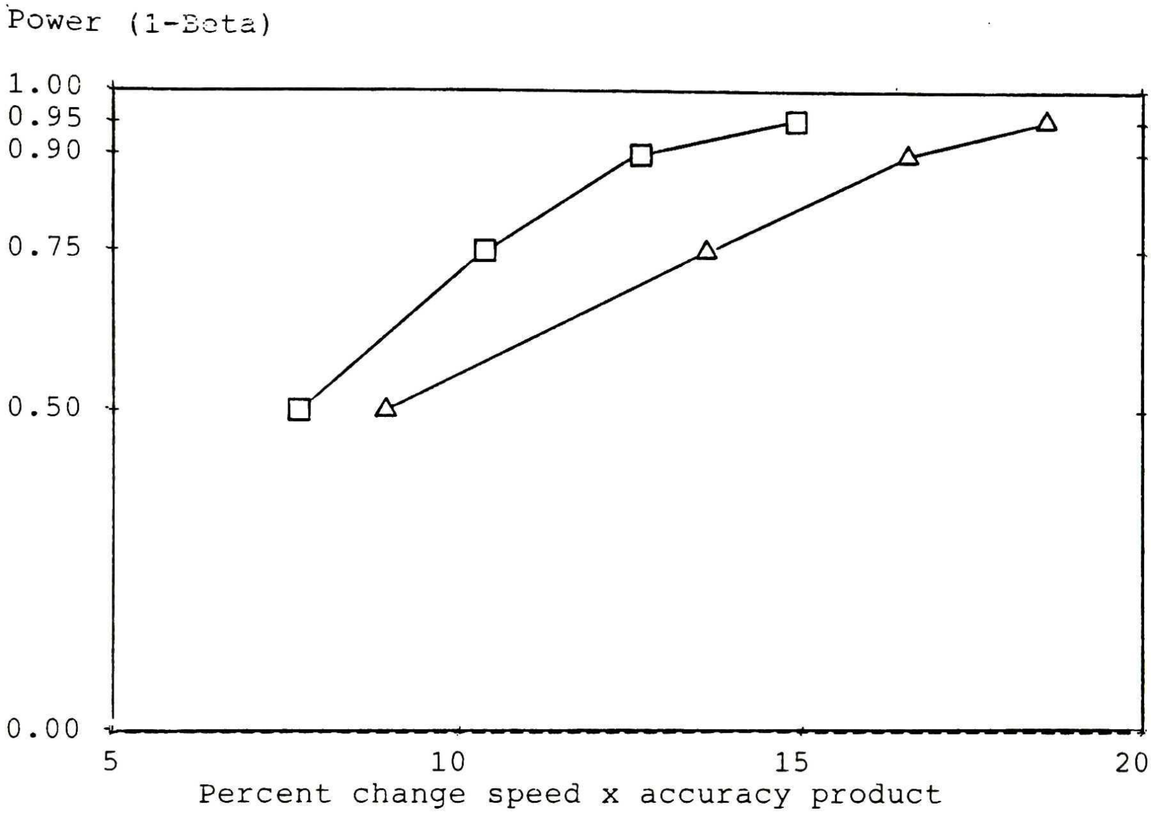


FIGURE 36. Graph of power (1 - Beta error) versus percent change in speed x accuracy product for LOGI. Squares are for 7,7 subjects and triangles are for 4,4 subjects.

FIGURE 37

Power vs size of detectable difference for PAULI

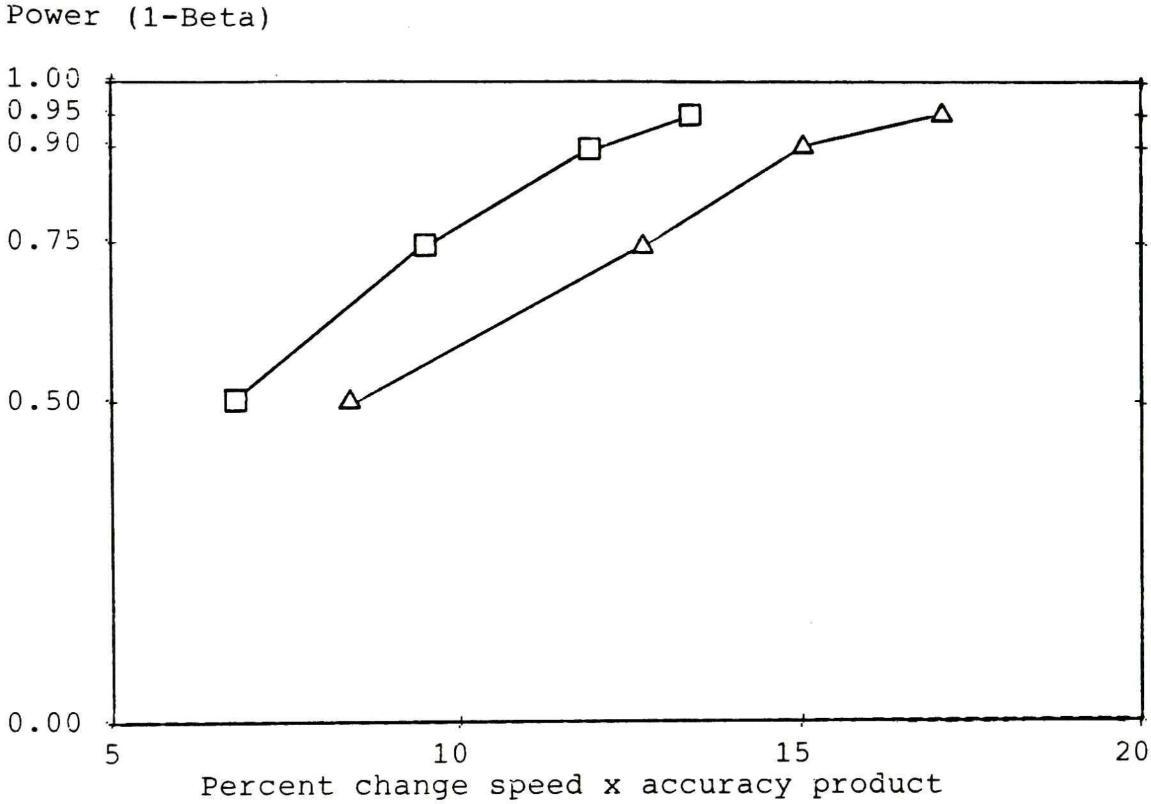


FIGURE 37. Graph of power (1 - Beta error) versus percent change in speed x accuracy product for PAULI. Squares are for 7,7 subjects and triangles are for 4,4 subjects.

FIGURE 38

Power vs size of detectable difference for MAT2

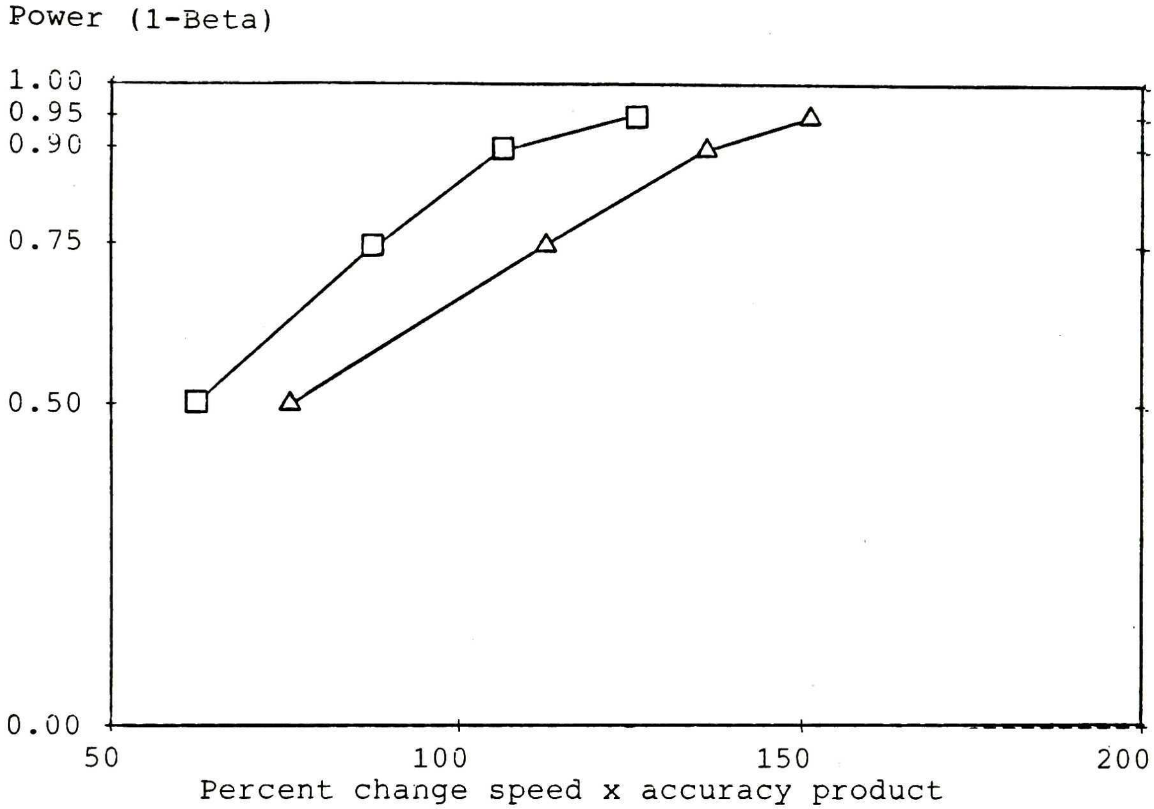


FIGURE 38. Graph of power (1 - Beta error) versus percent change in speed x accuracy product for MAT2. Squares are for 7,7 subjects and triangles are for 4,4 subjects.

Discussion

The purpose of the cross-sectional pilot study was to gain experience with the techniques involved, and to determine which tests would offer the greatest information from the longitudinal conditioning study. The pilot study was never intended to provide a definitive study of the effects of conditioning on mental performance. Nevertheless, the results are intriguing, especially the remarkably poor performance of the marathoner group on all subtests of the Performance Assessment Battery except the spatial ones (MAT1 and MAT2). The fact that only three marathoners were tested, and that they were significantly older than the other two groups, makes it impossible to derive firm conclusions from these data, irrespective of whether one considers the performance decrements to be due to the extremely strenuous training programs, or rather that only people who naturally perform poorly on mental performance tests voluntarily train themselves to this level. Further study is indicated, but the difficulties of designing a long-term program involving training of humans to these levels of physical fitness are extreme.

The pilot study indicated differences between the jogger and the sedentary groups for some but not all of the sub-tests of the PAB. The joggers and sedentaries performed equivalently on the two-digit addition (ADD2) task until 1200 hours, after which time the performance of the sedentary subjects fell off and the performance of the joggers

was maintained at a relatively constant level. This suggested a resistance to fatigue and/or a modification of the circadian rhythms of the joggers, and so this test was included in the longitudinal study. The joggers also scored higher in the logical decision making task (LOGI) at all times, and so this task was also included in the conditioning study. As it was determined that there was time for two other tasks in the conditioning study, it was decided to also use the spatial task (MAT2) as the only nonverbal task in the battery. It was found that performance on both MAT1 and MAT2 was identical, so it was unnecessary to include both. Also included was the single-digit addition task (PAULI), as it had the shortest reaction times of any task and was closest to a simple reaction-time.

In addition to the reasons for using ADD2, LOGI, PAULI, and MAT2 in the longitudinal study, the pilot study exposed flaws in the designs of MAST2, MAST6 and PROBEMEM which rendered them unsuitable. Specifically, it was always found that MAST2 and MAST6 covaried, whereas according to the literature they should have been out of phase with each other (Folkard, 1975; Folkard, 1979a; Folkard, 1979b). The problem may have been that the letters to be searched for were not erased but continuously displayed on the computer screen. It would thus be impossible to prevent 'cheating' on MAST6 by examining only the first two or three digits for a match, and only examining the remaining digits if the first ones were found. This would cause the immediate

memory loads of the tests to be identical, and would result in performance on MAST6 being slower than MAST2 but still correlating almost perfectly, which is what occurred. PROBEMEM was supposed to be a test of short-term memory, but many subjects complained that not enough time was allowed for them to scan all the digits before they were erased from the screen. This would mean that PROBEMEM measured a complex combination of short-term memory and 'visual scanning speed', rendering interpretation impossible. The defects in these tests, together with a practical limit of four tests to be included in the longitudinal study, led to their being discarded.

Effects of Age and Sex Differences

The subjects in the cross-sectional study were all males, but were not matched for age. The data on the effects of age on mental performance is confusing and appears to depend strongly upon the methodology used. However, the general consensus is that for the years between 20 and 60, there is a linear decrement in performance with age on the order of six percent per decade (Poon *et al.*, 1980). For the cross-sectional study, the sedentaries had a mean age of 28.9 years, the joggers 36.5 years, and the marathoners 44.7 years. This could have accounted for some but not all of the poor performance of the marathoner group, but could not have accounted for the higher performance of the joggers with respect to the sedentaries. For the longitudinal study the difference between the mean ages of

the control and exercise groups was five years, which would have implied a three percent difference. This difference in mean ages is not of sufficient magnitude to bias the study.

In the longitudinal study, two of the control group were female, but all members of the exercise group were male. The groups had initally been randomly selected but balanced for sex. However, both of the female subjects in the exercise group dropped out before completing the entire protocol. The responses of these two female control subjects did not differ significantly from the other five control subjects, and removing them from analysis does not alter the conclusions of the study. Also, while data does indicate some differences between the sexes in mental performance, especially those tests that measure hemispheric dominance (Chatterjea and Bakshar, 1982; Harshman _et_ _al_., 1983; Thompson _et_ _al_., 1981a), the absolute differences between the sexes are slight, on the order of five percent. Thus, this is not a significant bias to this study.

Effects of Motivation

Three of the subjects in the exercise group did not increase their maximal oxygen consumptions, but did increase their time on treadmill. There are two possible explanations for this result. First, all the subjects in the exercise group might have been motivated to run on the treadmill longer even though they may not all have had increases in aerobic conditioning. Both the researchers conducting the exercise stress tests and (obviously) the

subjects themselves knew who was in what group, so there may have been some percieved psychological pressure to stay on the treadmill longer the second time. If this were true, one would expect the maximal respiratory quotients (or RQ, the ratio of CO_2 production to O_2 consumption) to increase in the three subjects in the exercise group who did not have increases in VO2max. When work can no longer be supported by consumption of oxygen, it is supported by the anaerobic production of lactate. There is a correlation between changes in blood lactate levels and respiratory quotient (Clode and Campbell, 1969; Issekutz and Rodahl, 1961). This is due to the respiratory compensation for the metabolic acidosis caused by the increases in lactic acid. How long a subject can run after oxygen consumption has reached a plateau is a measure of motivation. The data in Table 12 support this conclusion by demonstrating that the three unconditioned subjects in the exercise group had increases in maximal RQ over the course of the study, with respect to the other 11 subjects in the study.

Even if training has not increased maximal oxygen consumption, it is possible that the percentage of maximal oxygen consumption at which lactate begins to rise may be increased. As it is the buildup of lactic acid which ultimately causes a subject to end a treadmill run, this would also result in a longer time on treadmill with no change in VO2max. Unfortunately it is very difficult to quantify the point at which lacate begins to build up (the

anaerobic threshold). This is because the increase in lactate occurs continuously and not all at once (Minken et al., 1983). However, one can plot the respiratory quotient (an index of lactate production) versus time on treadmill both before and after the conditioning period. If the curves are the same, then the time course of the lactic acid buildup is the same and a change in anaerobic threshold cannot be the explanation for the increased time on treadmill. This is illustrated in Figure 9, where the identical nature of the curves pre- and post- is demonstrated.

Cross-Sectional Versus Longitudinal Studies

To summarize the results of the longitudinal study, no changes were found in any index of mental performance as a result of aerobic conditioning. This was true whether the control group was compared with all seven subjects in the exercise group or just with the four subjects who had increases in maximal oxygen consumption. There were no differences between groups when changes were calculated as absolute differences and as percentage change from initial values, and when changes in oxygen consumption were correlated with changes in mental performance.

Thus the results of the cross-sectional study directly contradict the results of the longitudinal study. While the small number of subjects who successfully completed the longitudinal study meant that an actual increase of less than 10 to 15 percent could not be ruled out, this

was the size of the difference found between the sedentary and jogger groups for ADD2 and LOGI in the pilot cross-sectional study.

The current literature on the effects of aerobic conditioning on mental performance in normal healthy adults has many flaws. However, a parallel can be drawn between this study and the sleep literature. It has already been pointed out that many studies have demonstrated that people who choose to exercise regularly have different sleep patterns from those who do not. The one well-controlled longitudinal study found that the differences in the sleep patterns of conditioned subjects persisted even when the subjects were deconditioned (Paxton _et al_., 1983). This paper was written by researchers who in previous, less well-controlled studies had found that exercising had effects on sleep patterns (Montgomery _et al_., 1982). This strongly suggests that ability on mental performance tests is not independent of the choice to maintain a level of physical fitness. This reinforces the need to use well-controlled longitudinal studies, and casts further doubt on the validity of previous cross-sectional studies.

It should also be noted that if there had been no control group, positive results would have been found due to the effects of practice on some of the mental performance tests. This illustrates the problems with studies that do not use a control group. Also, only four out of the seven subjects in the exercise group had increases in maximal

oxygen consumption, even though when considered as a group all seven subjects in the exercise group had increases in time on treadmill when compared with the control group. While the conclusions of this study would have been unaffected, this demonstrates the problem with studies that do not measure maximal oxygen consumption or that use less reliable methods such as time to run a specified distance.

While previous studies on normal healthy adults were poorly designed, there is reliable data that aerobic conditioning has positive effects on mental performance in geriatric populations. This may be due to a mechanism not present in young to middle-aged study populations. Specifically, it has been hypothesized that decreases in mental performance with advancing age are due to atherosclerosis and decreases in brain perfusion and oxygen partial pressure (Sokoloff, 1975). Due to the ability of the healthy brain to autoregulate, this should not be a limiting factor in younger populations (Kety and Schmidt, 1948). Thus if aerobic conditioning caused increases in mental performance in older subjects by increased brain perfusion and oxygen consumption, this mechanism would not be expected to have any effects on younger populations.

Longitudinal Study: Changes in Circadian Rhythms

No circadian rhythms were detected in any group of subjects either before or after the conditioning period. Thus there was no effect of conditioning upon the circadian rhythms in mental performance. Compensating for the effects

of practice by assuming a linear increase in speed x accuracy product versus time and normalizing all the data for each individual subject to emphasize the within subject variability also revealed no circadian rhythmicity. The data from the pilot cross-sectional study, data from the use of the Performance Assessment Battery in other studies at the Walter Reed Army Institute of Research, and previous data in the literature (Colquoun, 1971; Wever, 1979a) demonstrate that the number of subjects in the study should have been adequate to detect a circadian rhythm in mental performance if one had existed.

There are several possible reasons for the observed lack of circadian rhythm. First, a previous study which examined the ability of house-staff to perform on an electrocardiogram pattern-recognition task during an extended work day, showed that house-staff can perform at a consistent level until fatigue levels become severe (Poulton _et al._, 1978). It is well known that the stress on house-staff is severe (Friedman _et al._, 1971). A study of circadian rythms during prolonged undersea voyages (Colquoun _et al._, 1978) demonstrated a reduction in the amplitude of the circadian rhythms. If the stress of a residency program were comparable this could have caused reduction or elimination of circadian rhythms by a similar process. However, it should be pointed out that other studies have determined that stress actually increases circadian rhythms (Bugge _et al._, 1979; Colquoun, 1971). Finally, unlike the cross-

sectional study, no controls were placed on the consumption of caffeinated beverages such as coffee. While caffeine cannot actually improve mental performance, it can prevent decrements of performance with fatigue (Goodman et al., 1980). It is possible that the unregulated consumption of coffee or other caffeinated beverages may have prevented any fatigue-related decrements of performance either early in the morning or late at night, resulting in the observed lack of effect of time of day on performance.

Conclusions

The results of this study indicate that an aerobic conditioning program has no significant effects upon the four measures of mental performance used in this study in a population of normal healthy adults free from significant pathology. No effects were noted on either baseline (average) performance or on variations in performance throughout the day (circadian rhythm).

It should be pointed out that while the study population was extremely well-matched, it cannot be considered to be indicative of the general population of healthy adults. The implications of this study are broad, but drawing conclusions to populations that do not have the educational background or extremely heavy work-loads of house-staff is of questionable utility. The lack of circadian rhythms in mental performance supports the premise that this study population is not representative of most normal healthy adults.

APPENDIX 1

Standard Form 88
Revised 10/75
General Services Administration
Interagency Comm. on Medical Records
FPMR 101-11.806-8

REPORT OF MEDICAL EXAMINATION

1. LAST NAME—FIRST NAME—MIDDLE NAME	2. GRADE AND COMPONENT OR POSITION	3. IDENTIFICATION NO.
4. HOME ADDRESS (*Number, street or RFD, city or town, State and ZIP Code*)	5. PURPOSE OF EXAMINATION	6. DATE OF EXAMINATION

7. SEX	8. RACE	9. TOTAL YEARS GOVERNMENT SERVICE		10. AGENCY	11. ORGANIZATION UNIT
		MILITARY	CIVILIAN		

12. DATE OF BIRTH	13. PLACE OF BIRTH	14. NAME, RELATIONSHIP, AND ADDRESS OF NEXT OF KIN
15. EXAMINING FACILITY OR EXAMINER, AND ADDRESS		16. OTHER INFORMATION
17. RATING OR SPECIALTY		TIME IN THIS CAPACITY (*Total*) / LAST SIX MONTHS

CLINICAL EVALUATION

NOTES (*Describe every abnormality in detail. Enter pertinent item number before each comment. Continue in item 73 and use additional sheets if necessary.*)

NORMAL	(*Check each item in appropriate column, enter "NE" if not evaluated.*)	ABNORMAL
	18. HEAD, FACE, NECK, AND SCALP	
	19. NOSE	
	20. SINUSES	
	21. MOUTH AND THROAT	
	22. EARS—GENERAL (*Int. & ext. canals) (Auditory acuity under items 70 and 71*)	
	23. DRUMS (*Perforation*)	
	24. EYES—GENERAL (*Visual acuity and refraction under items 59, 60 and 67*)	
	25. OPHTHALMOSCOPIC	
	26. PUPILS (*Equality and reaction*)	
	27. OCULAR MOTILITY (*Associated parallel movements, nystagmus*)	
	28. LUNGS AND CHEST (*Include breasts*)	
	29. HEART (*Thrust, size, rhythm, sounds*)	
	30. VASCULAR SYSTEM (*Varicosities, etc.*)	
	31. ABDOMEN AND VISCERA (*Include hernia*)	
	32. ANUS AND RECTUM (*Hemorrhoids, fistulae. Prostate, if indicated*)	
	33. ENDOCRINE SYSTEM	
	34. G-U SYSTEM	
	35. UPPER EXTREMITIES (*Strength, range of motion*)	
	36. FEET	
	37. LOWER EXTREMITIES (*Except feet*) (*Strength, range of motion*)	
	38. SPINE, OTHER MUSCULOSKELETAL	
	39. IDENTIFYING BODY MARKS, SCARS, TATTOOS	
	40. SKIN, LYMPHATICS	
	41. NEUROLOGIC (*Equilibrium tests under item 72*)	
	42. PSYCHIATRIC (*Specify any personality deviation*)	
	43. PELVIC (*Females only*) (*Check how done*) ☐ VAGINAL ☐ RECTAL	

(*Continue in item 73*)

44. DENTAL (*Place appropriate symbols, shown in examples, above or below number of upper and lower teeth.*)

Restorable teeth — Nonrestorable teeth — Missing teeth — Replaced by dentures — Fixed Partial dentures

R I G H T	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	L E F T
	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	

REMARKS AND ADDITIONAL DENTAL DEFECTS AND DISEASES

LABORATORY FINDINGS

45. URINALYSIS A. SPECIFIC GRAVITY			46. CHEST X-RAY (*Place, date, film number and result*)
B. ALBUMIN	D. MICROSCOPIC		
C. SUGAR			
47. SEROLOGY (*Specify test used and result*)	48. EKG	49. BLOOD TYPE AND RH FACTOR	50. OTHER TESTS

MEASUREMENTS AND OTHER FINDINGS

51. HEIGHT	52. WEIGHT	53. COLOR HAIR	54. COLOR EYES	55. BUILD: ☐ SLENDER ☐ MEDIUM ☐ HEAVY ☐ OBESE	56. TEMPERATURE

57. BLOOD PRESSURE (*Arm at heart level*)						58. PULSE (*Arm at heart level*)				
A. SITTING	SYS	B. RECUMBENT	SYS	C. STANDING (*3 min.*)	SYS.	A. SITTING	B. AFTER EXERCISE	C. 2 MIN. AFTER	D. RECUMBENT	E. AFTER STANDING 3 MIN.
	DIAS.		DIAS.		DIAS.					

59. DISTANT VISION		60. REFRACTION			61. NEAR VISION	
RIGHT 20/	CORR. TO 20/	BY	S.	CX	CORR. TO	BY
LEFT 20/	CORR. TO 20/	BY	S.	CX	CORR. TO	BY

62. HETEROPHORIA (*Specify distance*)

ES°	EX°	R. H.	L. H.	PRISM DIV.	PRISM CONV.	PC	PD
					CT		

63. ACCOMMODATION		64. COLOR VISION (*Test used and result*)	65. DEPTH PERCEPTION (*Test used and score*)	UNCORRECTED
RIGHT	LEFT			CORRECTED

66. FIELD OF VISION	67. NIGHT VISION (*Test used and score*)	68. RED LENS TEST	69. INTRAOCULAR TENSION

70. HEARING			
RIGHT WV	/15	SV	/15
LEFT WV	/15	SV	/15

71. AUDIOMETER	250 256	500 512	1000 1024	2000 2048	3000 2896	4000 4096	6000 6144	8000 8192
RIGHT								
LEFT								

72. PSYCHOLOGICAL AND PSYCHOMOTOR (*Tests used and score*)

73. NOTES (*Continued*) AND SIGNIFICANT OR INTERVAL HISTORY

(*Use additional sheets if necessary*)

74. SUMMARY OF DEFECTS AND DIAGNOSES (*List diagnoses with item numbers*)

75. RECOMMENDATIONS—FURTHER SPECIALIST EXAMINATIONS INDICATED (*Specify*)

76. A. PHYSICAL PROFILE

P	U	L	H	E	S

77. EXAMINEE (*Check*)

A. ☐ IS QUALIFIED FOR

B. ☐ IS NOT QUALIFIED FOR

B. PHYSICAL CATEGORY

A	B	C	E

78. IF NOT QUALIFIED, LIST DISQUALIFYING DEFECTS BY ITEM NUMBER

79. TYPED OR PRINTED NAME OF PHYSICIAN	SIGNATURE	
80. TYPED OR PRINTED NAME OF PHYSICIAN	SIGNATURE	
81. TYPED OR PRINTED NAME OF DENTIST OR PHYSICIAN (*Indicate which*)	SIGNATURE	
82. TYPED OR PRINTED NAME OF REVIEWING OFFICER OR APPROVING AUTHORITY	SIGNATURE	NUMBER OF ATTACHED SHEETS

☆ U.S.GPO:1979-0-281-187/4265

STANDARD FORM 93
REV. OCTOBER 1974
GSA FPMR 101-11.8

APPROVED
OFFICE OF MANAGEMENT AND BUDGET No. 29-R0191

REPORT OF MEDICAL HISTORY

(THIS INFORMATION IS FOR OFFICIAL AND MEDICALLY-CONFIDENTIAL USE ONLY AND WILL NOT BE RELEASED TO UNAUTHORIZED PERSONS)

1. LAST NAME—FIRST NAME—MIDDLE NAME	2. SOCIAL SECURITY OR IDENTIFICATION NO.
3. HOME ADDRESS *(No. street or RFD, city or town, State, and ZIP CODE)*	4. POSITION *(title, grade, component)*

5. PURPOSE OF EXAMINATION	6. DATE OF EXAMINATION	7. EXAMINING FACILITY OR EXAMINER, AND ADDRESS *(Include ZIP Code)*

8. STATEMENT OF EXAMINEE'S PRESENT HEALTH AND MEDICATIONS CURRENTLY USED *(Follow by description of past history, if complaint exists)*

9. HAVE YOU EVER *(Please check each item)*

YES	NO	*(Check each item)*
		Lived with anyone who had tuberculosis
		Coughed up blood
		Bled excessively after injury or tooth extraction
		Attempted suicide
		Been a sleepwalker

10. DO YOU *(Please check each item)*

YES	NO	*(Check each item)*
		Wear glasses or contact lenses
		Have vision in both eyes
		Wear a hearing aid
		Stutter or stammer habitually
		Wear a brace or back support

11. HAVE YOU EVER HAD OR HAVE YOU NOW *(Please check at left of each item)*

YES	NO	DON'T KNOW	*(Check each item)*	YES	NO	DON'T KNOW	*(Check each item)*	YES	NO	DON'T KNOW	*(Check each item)*
			Scarlet fever, erysipelas				Cramps in your legs				"Trick" or locked knee
			Rheumatic fever				Frequent indigestion				Foot trouble
			Swollen or painful joints				Stomach, liver, or intestinal trouble				Neuritis
			Frequent or severe headache				Gall bladder trouble or gallstones				Paralysis (include infantile)
			Dizziness or fainting spells				Jaundice or hepatitis				Epilepsy or fits
			Eye trouble				Adverse reaction to serum, drug,				Car, train, sea or air sickness
			Ear, nose, or throat trouble				or medicine				Frequent trouble sleeping
			Hearing loss				Broken bones				Depression or excessive worry
			Chronic or frequent colds				Tumor, growth, cyst, cancer				Loss of memory or amnesia
			Severe tooth or gum trouble				Rupture/hernia				Nervous trouble of any sort
			Sinusitis				Piles or rectal disease				Periods of unconsciousness
			Hay Fever				Frequent or painful urination				
			Head injury				Bed wetting since age 12				
			Skin diseases				Kidney stone or blood in urine				
			Thyroid trouble				Sugar or albumin in urine				
			Tuberculosis				VD—Syphilis, gonorrhea, etc.				
			Asthma				Recent gain or loss of weight				
			Shortness of breath				Arthritis, Rheumatism, or Bursitis				
			Pain or pressure in chest				Bone, joint or other deformity				
			Chronic cough				Lameness				
			Palpitation or pounding heart				Loss of finger or toe				
			Heart trouble				Painful or "trick" shoulder or elbow				
			High or low blood pressure				Recurrent back pain				

12. FEMALES ONLY: HAVE YOU EVER

YES	NO	DON'T KNOW	
			Been treated for a female disorder
			Had a change in menstrual pattern

13. WHAT IS YOUR USUAL OCCUPATION?

14. ARE YOU (Check one)

☐ Right handed ☐ Left handed

YES	NO	CHECK EACH ITEM YES OR NO. EVERY ITEM CHECKED YES MUST BE FULLY EXPLAINED IN BLANK SPACE ON RIGHT	
		15. Have you been refused employment or been unable to hold a job or stay in school because of: A. Sensitivity to chemicals, dust, sunlight, etc.	
		B. Inability to perform certain motions.	
		C. Inability to assume certain positions.	
		D. Other medical reasons *(If yes, give reasons.)*	
		16. Have you ever been treated for a mental condition? *(If yes, specify when, where, and give details).*	
		17. Have you ever been denied life insurance? *(If yes, state reason and give details.)*	
		18. Have you had, or have you been advised to have, any operations? *(If yes, describe and give age at which occurred.)*	
		19. Have you ever been a patient in any type of hospitals? *(If yes, specify when, where, why, and name of doctor and complete address of hospital.)*	
		20. Have you ever had any illness or injury other than those already noted? *(If yes, specify when, where, and give details.)*	
		21. Have you consulted or been treated by clinics, physicians, healers, or other practitioners within the past 5 years for other than minor illnesses? *(If yes, give complete address of doctor, hospital, clinic, and details.)*	
		22. Have you ever been rejected for military service because of physical, mental, or other reasons? *(If yes, give date and reason for rejection.)*	
		23. Have you ever been discharged from military service because of physical, mental, or other reasons? *(If yes, give date, reason, and type of discharge: whether honorable, other than honorable, for unfitness or unsuitability.)*	
		24. Have you ever received, is there pending, or have you applied for pension or compensation for existing disability? *(If yes, specify what kind, granted by whom, and what amount, when, why.)*	

I certify that I have reviewed the foregoing information supplied by me and that it is true and complete to the best of my knowledge.
I authorize any of the doctors, hospitals, or clinics mentioned above to furnish the Government a complete transcript of my medical record for purposes of processing my application for this employment or service.

TYPED OR PRINTED NAME OF EXAMINEE	SIGNATURE

NOTE: HAND TO THE DOCTOR OR NURSE, OR IF MAILED MARK ENVELOPE "TO BE OPENED BY MEDICAL OFFICER ONLY."
25. Physician's summary and elaboration of all pertinent data *(Physician shall comment on all positive answers in items 9 through 24. Physician may develop by interview any additional medical history he deems important, and record any significant findings here.)*

TYPED OR PRINTED NAME OF PHYSICIAN OR EXAMINER	DATE	SIGNATURE	NUMBER OF ATTACHED SHEETS

☆ GPO : 1977 O - 261-647 (3261)

APPENDIX 2

CONSENT EXPLANATION SHEET
PATIENT EXPLANATION CONSENT FORM

Institute: Walter Reed Army Medical Center, Washington,D.C.,20307

Title of protocol: A Study of the Impact of an Exercise Prescription and Personal Guidance on Fitness Program Compliance and the Effect of Fitness on Mental Performance

Principal Investigators: Margarete Di Benedetto, M.D., COL, MC
J. Michael Long, M.D., MAJ, MC

Participant Information: You have been asked to participate in the research study conducted at the Walter Reed Army Medical Center. It is very important that you read and understand the following general principles which apply to all participants in our studies, whether normal or patient wolunteers:

a) Your participation is entirely voluntary.
b) you may withdraw from participation in this study or any part of the study at any time. Refusal to participate will involve no penalty or loss of medical benefits to which you are entitled.
c) After you read the explanation, please feel free to ask any questions that will allow you to clearly understand the nature of this study.

Nature of the study: The purpose of the study is to document the effect individualized exercise prescriptions have on the adherence in an exercise program designed to improve aerobic fitness. We will also document the physiologic measures of physical fitness, and investigate the effect of physical fitness on mental performance.

For your explanation, the study will be divided into four phases: screen, test, exercise, and retest.

PHASE I - The SCREEN: Initially you will be screened for coronary risk with a medical chart review and physical exam including laboratory work requiring 14cc's of blood. If you are found to have greater than 5% risk of developing coronary heart disease in the next six years , you will be excluded from the study and referred to cardiology for follow up. Next you will be administered a multivariate test of determine your level of self motivation which will be used to match individuals and to develope your individual exercise prescriptions. You will also be weighed and your skin fold thickness will be determined. This information is also needed to match our experimental groups.

PHASE II - THE TEST: From the information obtained in the Screen, 15 matched groups will be formed on the basis of age, sex, percent body fat,

and level of self motivation. You may not match and may be excluded from the study at this point. If you match, you will be subjected to several tests of current level of exercise tolerance. These tests will be conducted at the Exercise Physiology Lab at USUHS and in the Physical Therapy Gym on the third floor of WRAMC.

These tests include:

1) Physiologic measurements

a) Graded exercise tolerance test (Bruce protocol)
b) Aerobic capacity (maximun oxygen uptake; Vo2 max)
c) Cybex isokinetic muscle testing of shoulder abbductors, flexors,and extensors; elbow flexors and extensors; hip flexors and extensors; and knee flexors and extensors.
d) Lean body weight and per cent body fat determined by hydrostatic weighing.

2) Mental performance tests

a) Computerbased mental performance assessment battery (PAB) administered three times initially for practice, then ten times, at two hour intervals throughout the day. Approximately one mounth will be required to complete this phase, so that the tests are distributed over many days.
b) Computerbased mood scale to be administered before each PAB.
c) Oral temperature measured at each PAB.
d) The Wechsler Adult Intelligence Scale administered once.
e) A postsleep evaluation of the quality of sleep to be performed three times.

<u>EXPLANATION OF THE TESTS:</u>

1. The PAB mental performance test was developed at the Walter Reed Army Institute of Research (WRAIR). It consists of four subtests measuring arithmetic computation speed, logical reasoning speed, short-term memory, and a visual search task. It is reproducible and largely independent of intelligence level when administered to individuals of average intelligence. The test has been designed to run on an Apple II computer and automatically records and times each response to the nearest 5 milliseconds. Total time for a test should not exceed 12 minutes.

2. A computerized adjective checklist will be administered just before each PAB session. It has also been developed at WRAIR and consists of a randomized list of 65 adjectives. Composite measures derived from this scale include total positive feelings, total negative feelings, subjective fatigue, etc.

3. The post-sleep inventory was developed by Wilse B. Webb at the University of Florida, Gainesville, and consists of 29 items to be filled out immediately upon awakening. This provides a measure of the subjective quality of a subject's sleep.

4. Also to be used are four subtests of the Wechsler Adult Intelligence Scale to include the Arithmetic, Digit Span, Digit Symbol, and Block Design subtests. It is highly reproducible and need be given only one at the start of the study and once at the end.

PHASE III - THE EXERCISE PROGRAMS:

STAGE A: The two exercise groups and the non-exercise control group will be given the results of the testing in Phase II and lectured on the basic principles of exercise physiology as it relates to strength training and cardiovascular conditioning. They will also be instructed in the maintenance of accurate exercise logs.

STAGE B: The non-exercise control group will be instructed not to engage in a regular exercise program which could enhance aerobic fitness (increase $VO_{2\ max}$). Exercise group A will be given the standard Army guidelines for exercise training and health maintenance. Exercise Group B will be given an individualized exercise program designed to provide daily guidance for improving strength and endurance of specific muscle groups as well as improving cardiovascular condition. It will be based upon the subject's VO_{2max}, lean body weight, desired means of improving aerobic condition (e.g., swimming, biking, jogging, etc.), the number of days/week during which exercise may be performed, and the self-motivation index.

All subjects in all three groups will meet with a member of the Physical Medicine/Rehabilitation Service at least every two weeks for a review of the exercise log, adjustment of the exercise program, and treatment of any injuries.

PHASE IV - RETESTING AND DATA ANALYSIS:

STAGE A: Repeat physiologic tests in Phase II at the Exercise Lab, USUHS. Repeat mental performance tests.

STAGE B: Collect and evaluate adherence data.

STAGE C: Statistical analysis of all data collected.

STATISTICS: Standard statistical procedures for the analysis of paired comparison data will be utilized in this investigation. For all individuals, the matched pairs (treatment versus control) will be compared on each variable. The numerical difference in each pair's measure of change will be computed, variance calculated and a t-test performed to determine if group differences are significant.

PARTICIPANT ATTITUDES: All individuals will be screened as they finish the program to determine their attitudes about it and their intentions about continuing with an exercise program on their own. We will attempt to determine their perceived benefits from the exercise prescription, the tracking reports, and in the case of controlled group participants their feelings about the value and quality of standard Army guidance material for developing and maintaining physical fitness. All subjects who had been randomly assigned to the non-exercise control group or exercise group A (standard Army guidelines for fitness) will be given the opportunity to undergo aerobic conditioning by means of the individualized prescriptions as provided to exercise group B.

RESEARCH REPORT: All results will be documented in a research report which will fully describe the program and the analysis done. Test data will be organized independent to the report to complete the investigation.

BENEFIT: The well documented association between regular moderate exercise and health benefits makes it clear that the potential of a program designed to improve your compliance is of great importance to you in your attempts to maintain your optimal level of physical and mental fitness. Your participation in this protocol will give you a unique opportunity to have a thorough analysis of your personal physical fitness levels and body composition. All of your own results will be available to you, and regardless of the group that you were in, an individualized exercise program will be provided to you when the project is terminated.

DURATION OF THE STUDY: The study will run from July 1983 to January 1984.

RISKS, INCONVENIENCES AND DISCOMFORTS: There is a risk of sudden death. Maximal exercise testing can be hazardous in older individuals with undetected cardiovascular disease. The EKG monitoring and the progressive nature of the test minimize any risks, so that in you and in healthy individuals, the risk is minimal.

There is a risk of muscle strain, and ligament sprain while performing the exercises.

Blood samples will be drawn initially and at the end of the exercise period (three months)

SAFEGUARDS: Prior to any exercises or testing, the AMA Coronary Risk Screen will be administered. While this screen does not guarantee cardiovascular health, it is widely used to guage those individuals at the greatest risk for developing coronary heart disease. Also, a physician and a Certified Cardiac Exercise Technician will be present at all treadmill testing.

The risk of muscle strain and ligament sprain will be minimized by the thorough physical testing which will give all participants the ability to gradually increase the stress on his musculoskeletal system by knowing presisely what there current level of fitness is. Also, there will be

contact with a Physiatrist every two weeks to review the exercise log and to help prevent over use syndromes. He will also be available on an emergency basis for treatment of any injuries that may occur.

A subject may drop out at any time.

CIRCUMSTANCES UNDER WHICH YOUR PARTICIPATION MAY BE TERMINATED WITHOUT YOUR CONSENT:

a) Health conditions under which your participation may be dangerous.

b) Other conditions which might occur that would make your participation detrimental to you or your own health.

c) Noncompliance

COST TO YOU: No cost.

SIGNIFICANT NEW FINDINGS: Any significant new information regarding new findings that develop during the study will be made available to you.

NUMBER OF SUBJECTS IN THE STUDY: Screen approximately 150 interns and residents, male and female, nonsmokers. Group into three matched groups with 15 subjects in each group.

FOR FURTHUR INFORMATION: Please contact J. Michael Long,M.D., MAJ, MC,
Physical Medicine Service
Phone - 576-1368

For further information regaurding the rights of research subjects, please contact the Center Judge Advocate Office at 576-4096, 4097.

SIGNATURES:

____
PATIENT/VOLUNTEERS

____
INVESTIGATOR

____________________________ ____________________________
DATE & TIME WITNESS

APPENDIX 3

INSTRUCTIONS USUHS/WRAMC EXERCISE STUDY

These are the instructions for taking the Performance Assessment Battery ("PAB") on the Apple II microcomputer. First, make sure the power is off. Then locate the floppy diskette with your name on it and insert it into the disk drive. Do not touch the areas exposed by the cutouts in the cardboard sleeve!! The diskette is inserted with the label facing towards you and up. Close the little hatch, and then turn the power on. The machine will whirr and click for a little while, and then will ask you to type in your name, the date, the time, and the trial number (=1 for the first time you take it, =2 for the second etc.). The computer will then automatically cycle through the moodscale and the four mental performance subtests. Instructions for these are located below. At the end of the session, replace your diskette in the file and turn the power switch off.

Please remember that you must complete three practice sessions before doing the performance assessment battery 'for real'. Operation of the computer is the same as described above, but you will use one of the practice disks NOT the one with your name on it. The practice sessions do not include the moodscale, and a "C" (correct) or an "E" (error) will flash on the screen after each response to help you get used to the different tests.

ADD2 INSTRUCTIONS

This test will involve adding together a column of 5 two-digit numbers. You may not use paper or pencil, although you may use your fingers to help remember the one's digit if you want to. Type in the answer (typically a three-digit number) and then the 'return' key. You cannot erase an incorrect entry. Try to work both as accurately and quickly as possible,- this test is scored by taking the percentage correct and dividing by the average reaction time.

LOGI INSTRUCTIONS

This is a test of logical decision making. A logical statement will display on the left of the screen, and the two letters "A" and "B" will display on the right, as either "AB" or "BA". You must decide if the statement correctly decribes the relative order of these two letters,- if it does type "S", if not type "D". As before both speed and accuracy count.

PAULI INSTRUCTIONS

This test will involve adding two one-digit numbers. The first digit will flash on the screen, followed by a second digit, followed by either the plus or the minus sign. In all cases you will simply type a single digit for the answer. If the answer is greater than ten, type in only the last digit, and if the answer is a negative number add the result to +10 to get the answer. As before, try to maximize both speed and accuracy,- This test is scored by taking the percent correct - 50 (so that random guessing yields zero) and dividing by the average reaction time.

Examples:	First	Second	Sign	Answer
	2	2	+	4
	4	7	+	1
	7	5	-	2
	3	4	-	9

MATRIX2 INSTRUCTIONS

This is a test of spatial perception and memory. A pattern of stars will flash on the screen, followed by either the same pattern or a slightly different pattern. Type "S" if the second pattern is the same as the first and "D" if it is different. Try to maximize both speed and accuracy.

APPENDIX 4

NAME ____________

WEEKS ____________

Monday____________
Activities:

Pulse rate pre-exercise___, min post___.
Duration of exercise___ minutes.

Tuesday____________
Activities:

Pulse rate pre-exercise___, min post___.
Duration of exercise___ minutes.

Wednesday____________
Activities:

Pulse rate pre-exercise___, min post___.
Duration of exercise___ minutes.

Thursday____________
Activities:

Pulse rate pre-exercise___, min post___.
Duration of exercise___ minutes.

Friday____________
Activities:

Pulse rate pre-exercise___, min post___.
Duration of exercise___ minutes.

Saturday____________
Activities:

Pulse rate pre-exercise___, min post___.
Duration of exercise___ minutes.

Sunday____________
Activities:

Pulse rate pre-exercise___, min post___.
Duration of exercise___ minutes.

Subjective summary:

Morning Pulse; Monday___, Tuesday___, Wednesday___, Thursday___, Friday___, Saturday___, Sunday___.

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